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REGULAR ARTICLES

Leptin, adiponectin, biochemicals, metabolic hormones and performance characteristics of broiler administered with spices essential oil

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Abstract

A study was conducted to evaluate adipokines, metabolic hormones and serum biochemicals of broiler chicken administered with essential oils (EO) of turmeric, ginger, cinnamon and garlic. EO of the four spices were extracted by steam distillation using standard procedures. The EO were administered to 200 one- day-old unsexed broiler birds randomly allotted to five treatment groups (each of the four spices EO plus a control group) replicated 10 times in a completely randomized design. The spices EO were added to water consumed by the birds at 30 ml/L and standard diets were fed in a 42-day feed trial to determine weight changes and feed consumption. At the end of the trial, blood samples were collected, serum obtained and were assayed for metabolic and biochemical indicators. Results obtained indicates that the weight gain trends shows that birds on cinnamon EO and garlic EO were significantly ($p < 0.05$) higher than those on turmeric EO. Abdominal fat of birds on EO were significantly ($p < 0.05$) lesser than birds on control. Cholesterol of birds on EOs-based treatments were significantly ($p < 0.05$) lesser than birds on control. Triiodothyronine of birds were not significantly influenced by EOs. Insulin of birds on EOs were statistically ($p < 0.05$) reduced compared with those on control. Consumption of cinnamon EO significantly ($p < 0.05$) increased adiponectin of birds compared with garlic EO. Intake of garlic EO significantly ($p < 0.05$) enhance leptin of birds compared with cinnamon EO. This study suggests that cinnamon and garlic EO are potent oral phytogenic supplements to promote growth and lean yield in broiler chicken.

Keywords Adipokines · Insulin · Growth · Appetite · Cinnamon

Introduction

Antibiotics with growth promoting potential are utilized in broiler production (Mehdi et al. 2018), but with inclining trends of microbial defiance, as resulted to heightened demand to eradicate antibiotics growth promoters (Stefanello et al. 2019). Among alternatives to antibiotics growth promoters are herbal extracts, with bioactive molecules capable to elucidate beneficial physiological and metabolic effects on animals (Marcin et al. 2016). Herbs and spices are crrently utilized in animal nutrition owing to their potency to promote medicinal effects in livestock and poultry (Jimoh et al. 2018, 2022), as substitute to growth promoting antibiotics. The increasing use of medicinal plants in poultry diets due to growth promotion, antioxidant, antimicrobial, improved sensory quality and consumer acceptability of products, reduced drug use and chemical additives, and improving physiology and

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immunity of the animals (Ayodele et al. 2021; Oloruntola et al. 2022) is currently gaining wide acceptance.

EO are rich variable complex of terpenoids (monoterpenes and sesquiterpenes) (Nazzaro et al. 2013) and are hydrophobic liquid of unstable aromatic compounds (polyphenols, flavone, aldehyde, terpenoids, phenol, quinone, methoxy-derivative, tannins, saponins, esters, flavonoids) (Herve et al. 2019). Plant-derived EOs are among the potential alternatives to antibiotics growth promoter, having exhibited numerous biological activities such as immune-modulation, antioxidants and antimicrobials (Su et al. 2021). EOs possess the potential to manipulate digestion and productivity in animals, by enhancing secretion of digestive enzymes, promoting blood circulation, enhancing antioxidant activity, reducing microbial pathogens and enhance immunity (Marcin et al. 2016), which in turn can decrease negative energy balance and promote absorption of nutrients to trigger enhanced growth and reproductive output in animals (Herve et al. 2019). EO usually affects carrier's (feed/water) smell and taste, leading to higher digestive enzyme activity, secretion of gastric juices and saliva (Zhang et al. 2020; Su et al. 2021).

Performance indices of birds were promoted by the inclusion of EOs in their drinking water (Tekce et al. 2020). EOs have been shown to enhance digestion (Lee et al. 2004), and to improve the nutrients absorption (Hernandez et al. 2004). Some EOs commonly used in broiler productions are oregano, cinnamon, ginger, garlic, thyme, and turmeric (Lee et al. 2003).

Nemati et al. (2021) reported that ginger possesses several active compounds to stimulate digestive enzymes and feed digestion, thereby promoting feed consumption and efficiency of feed utilization. The positive growth effect of garlic is due to allicin, that promotes the intestinal flora thereby improve digestive events (Abd El-Latif et al. 2013). *Curcuma longa* (turmeric) possess antioxidant, antimicrobial, antifungal, antimutagenic and antidiabetic properties (Gowda et al. 2009; Daramola et al. 2020a, b) and growth promoting effects (Ürüşan and Bölükbaşı 2020). Aromatic smell and taste of *Curcuma longa* is owing to its EOs, extracted by distillation from herbs and spices (Adaszyńska-Skwirzyńska and Szczerbińska 2017). Cinnamon bioactive compounds (cinnamaldehyde and transcinnamaldehyde) promotes growth hormones and its EOs can improve feed intake and utilization in birds (Krishan and Narang 2014).

Despite the promising results from various studies on EOs in broiler production, there remains a notable gap in the comparative analysis of their effects. While literature indicates that Garlic EO is rich in allicin, Ginger EO contains significant amounts of zingiberene and β-sesquiphellandrene, Turmeric EO, primarily composed of curcumin, as well as turmerones, Cinnamon EO features cinnamaldehyde as its main active component, indicating their beneficial properties (Lee et al. 2003, 2004; Hernandez et al. 2004; Nemati et al. 2021; Abd El-Latif et al. 2013; Gowda et al. 2009; Adaszyńska-Skwirzyńska and Szczerbińska 2017; Krishan and Narang 2014), and their roles in promoting growth, improving digestion, and enhancing nutrient absorption are acknowledged. Comprehensive comparative studies on these EOs are limited. Few studies have been carried out to compare the efficacy of different spices EOs on the performances of broilers (Yang et al. 2019). Existing research often focuses on individual EOs or their broad effects without directly comparing their relative efficacy on specific performance metrics in broilers. For instance, studies have highlighted the growth-promoting and health benefits of individual oils like garlic or turmeric (Ayodele et al. 2021; Oloruntola et al. 2022), but few have systematically compared the effects of multiple EOs in a single study. Adaszyńska-Skwirzyńska and Szczerbińska (2017) noted the need for further research but did not address the comparative aspects explicitly. Metabolic hormones like T3 and insulin are crucial for understanding how EOs affect metabolic processes. T3 is involved in metabolism regulation, while insulin plays a role in glucose metabolism. Assessing these hormones helps reveal how EOs influence metabolic rate and glucose homeostasis. Adipokines like adiponectin and leptin are involved in regulating appetite, energy expenditure, and fat metabolism. By measuring adiponectin and leptin levels, the study can infer how EOs affect fat metabolism and appetite regulation. This study aims to address this gap by providing a direct comparison of the effects of garlic, turmeric, ginger, and cinnamon EOs on growth, metabolic hormones, and biochemical indices in broiler chickens. By isolating and comparing these variables, this research seeks to offer clearer insights into the relative efficacy of these EOs and their potential as alternatives to antibiotic growth promoters.

Materials and methods

Phytogenics processing and evaluation

Fresh and mature garlic, turmeric, ginger and cinnamon were procured at a local spices retailer in Ado-Ekiti, Ekiti State, Nigeria. They were peeled, diced and blend until the mixture is thoroughly homogenized in water (40% w/v) and a uniform slurry is obtained The homogenized mixture was transferred to a Clevenger-type apparatus for hydrodistillation (Katekar et al. 2022, 2023). The distillation lasted for 4 h to ensure maximum extraction of EOs. Once the distillation process is complete, the mixture is allowed to cool and the EO is separated from the aqueous layer using a separating funnel. The extracted EO was dehydrated and stored in sealed glass vials below 18 °C. Garlic EO is rich in allicin, Ginger EO contains significant amounts of zingiberene and

β-sesquiphellandrene, Turmeric EO, primarily composed of curcumin, as well as turmerones, Cinnamon EO features cinnamaldehyde as its main active component.

Experimental animals and management

The study was conducted in the Teaching and Research farm of the Federal Polytechnic Ado Ekiti, with 200 a-day old Arbor Acres mixed sexed broilers weighing 43.85 ± 3.78 g were obtained from a commercial hatchery in Ibadan, Oyo State, Nigeria. The birds were weighed, and then randomly assigned to five treatment groups in a completely randomized design. Each treatment included 10 replicates, with 4 birds per replicate. The poultry facility consist of a single pen (5 × 10 × 3 m; width x length x height), naturally lighted (12D:12 L) with a dynamic ventilation system. The poultry pen is evenly distributed with 40 double sided and floored wire mesh cage units of $1m^2$ per unit, 30 cm each feeding and drinking space per unit, with an average temperature of 25.47 °C. The treatments were as follows: a control group with no supplement, garlic EO, ginger EO, turmeric EO, and cinnamon EO. Experimental broiler starter and finisher basal diets were compounded to suit the nutrient requirement as shown in Table 1 and fed to the birds for 21 days each. The spices EOs were supplemented into drinking water (30 ml/1L) (a high-speed blender used to create a fine emulsion of EO in water, on daily basis) for the birds throughout the study. Birds were offered fresh water and feed ad libitum, while the actual intake of feed and water were monitored. No medication was offered, only hatchery recommended vaccination programme (The birds were vaccinated against gumboro disease at the end of weeks 1 and 3, using Infectious Bursal Disease Vaccine (IBDV) and Newcastle Disease Vaccine (Lasota) at the end of 2nd and 4th weeks.) were followed.

The feed intake and weight changes were monitored throughout the study to evaluate their growth in a 42-day trial. Feed conversion were computed per replicate. Performance evaluation: feed intake, weight changes were monitored weekly and feed conversion ratios (FCR) was deduced from ratio of weight gain to feed intake. Weight intake was monitored daily, by subtracting the volume of leftover from water offered.

Blood sample collection

At the end of the trial, fastened blood samples were collected through the Brachial vein from 3 birds per replicate into sterile bottles. The samples were centrifuged and serum collected following standard procedures and stored at −20 °C for further analysis.

Table 1 Gross composition of broiler ration (% as fed basis)

Ingredient(%)	Starter diet	Finisher diet
Maize	58.50	66.50
Groundnut cake	9.80	8.30
Soyabean meal	25.00	19.50
Fishmeal	3.10	2.00
Methionine	0.25	0.25
Lysine	0.25	0.25
Oyster shell	1.50	1.50
Limestone	1.10	1.20
*Premix	0.25	0.25
Salt	0.25	0.25
Total	100.00	100.00
Dry Matter %	85.85	85.55
Crude Protein %	22.99	18.58
Metabolisable Energy kcal/kg	3031.27	3086.43
Ether Extract %	3.94	3.93
Crude fibre %	3.32	3.03
Lysine %	1.38	1.17
Methionine %	0.61	0.56
Calcium %	1.17	1.16
Phosphorus %	0.32	0.48

*Premix composition per kg diet: Vit A:400000 IU, Vit D:80000 IU, Vit E:40000 ng, Vit k3:800 mg, Vit B1:1000MG, Vit B2:6000 mg, Vit B6:500 mg, VitB12:25 mg, Niacin:6000 mg, Panthothenic acid:2000 mg, Folic acid: 200 mg, Biotin:8 mg, Manganese:300000 g, Iron:8000 mg, Zinc:20000 g, Cobalt:80 mg, Iodine:400 mg, Selenium:40 mg, Choline:800000 g

Serum biochemical assay

Biochemical assays for low density lipoprotein (LDL), albumin, alanine amino transferase (ALT), creatinine, Aspartate amino transferase (AST), cholesterol, glucose, urea, triglyceride, globulin, high density lipoprotein (HDL), total protein were carried out using fortress diagnostics commercial assay kits (Fortress Diagnostics Limited, Unit 2C Antrim Technology Park, Antrim, BT41 1QS, United Kingdom) and its procedures.

Hormonal assay

Serum was evaluated for triiodothyronine and insulin, using enzyme linked immunosorbent assay, with ELISA kits and its procedure for individual assay.

- Triiodothyronine (T3) ELISA Catalog No. T3225T (Calbiotech Inc., 1935 Cordell Ct., El Cajon, CA 92020)
- Insulin ELISA kit, Catalog No. IS130D (Calbiotech Inc., 1935 Cordell Ct., El Cajon, CA 92020)

Adipokines assay

Serum was evaluated for adiponectin and leptin using enzyme linked immunosorbent assay, with ELISA kits and its procedure for individual assay.

- Adiponectin ELISA Kit, Cat.No E0758Ra (Bioassay Technology Laboratory, www.bt-laboratory.com, 1008 Junjiang Inter. Bldg. 228 Ningguo Rd. Yangpu Dist. Shanghai. China)
- Leptin ELISA Kit, Cat.No E0561Ra (Bioassay Technology Laboratory, www.bt-laboratory.com, 1008 Junjiang Inter. Bldg. 228 Ningguo Rd. Yangpu Dist. Shanghai. China)

At the end of the study, the birds were not offered feed overnight, three birds per replicate were randomly chosen and humanely sacrificed by cutting through the jugular vein, carotid artery, and windpipe and eviscerated using standard procedures to obtain relative organ weight. The organs were carefully removed and weighed appropriately. The empty weight of the proventriculus and gizzard and the weight of whole heart, lungs, kidney, gall bladder, abdominal fat, head, shank, spleen, liver, pancreas and small intestine were recorded.

Statistical analysis

The statistical model applied is as follows:

$$Y_{ijl} = \mu + B_i + e_{ijl}$$

where Y_{ijl} represents the value of performance, serum biochemicals, hormonal profile and adipokines measured in the l^{th} animal; μ is the overall mean for each character; B_i is the fixed effect of i^{th} spices EOs administered; and e_{ijl} is the random residual effect.

Data obtained from the study was analysed using generalized linear model procedure of one-way Analysis of variance, and means were separated using new Duncan's multiple range test according to statistical analysis software IBM SPSS 20.

Results

The performance of broilers on different spices EOs is shown in Table 2. The final weight of birds on Cinnamon EO and Garlic EO were significantly ($p < 0.05$) higher than those of birds on control and ginger EO, which had statistically ($p > 0.05$) similar values. The birds on turmeric EO had the significantly ($p < 0.05$) least final weight. The weight gain trends shows that birds on cinnamon EO and garlic EO had significantly higher values than those of birds on turmeric EO. The feed intake (FI) of birds on EOs-based treatment were higher than the birds on the control. The FCR on turmeric EO was significantly ($p < 0.05$) higher than birds on the control, while birds on ginger EO, garlic EO and cinnamon EO were statistically ($p > 0.05$) similar with other treatments. Water intake of birds on cinnamon EO and control were statistically ($p < 0.05$) higher than other treatments, while birds on ginger EO had the significantly ($p < 0.05$) least values.

The relative organ weights of birds on spices EO are shown in Table 3. The trend of result show that relative weights of head, shank, lung, heart, liver, gizzard and pancreas were not significantly ($p < 0.05$) affected by the EO intake. The relative carcass weight of birds on turmeric EO was statistically ($p < 0.05$) superior to other treatments, birds on cinnamon EO and control had significantly ($p < 0.05$) higher values than birds on garlic EO and ginger EO. Crop of birds on turmeric EO were significantly higher ($p < 0.05$) than those of birds on control, garlic EO and cinnamon EO, which share statistically ($p > 0.05$) similar values. The proventriculus weight of birds on cinnamon EO was significantly ($p < 0.05$) higher than those of birds on garlic EO. Weight of intestine of birds of garlic EO and turmeric EO were significantly ($p < 0.0$) higher than those of birds on ginger EO, while the significantly ($p < 0.05$) least values were recorded in birds on control and cinnamon EO. The kidney weight of birds on garlic EO and ginger EO were statistically

Table 2 Performance characteristics of broilers on different spices essential oils

	Control	Garlic EO	Ginger EO	Tumeric EO	Cinnamon EO	SEM
Initial Weight (g)	68.42	67.13	67.12	65.70	65.99	1.28
Final Weight (g)	1467.26^{b}	1483.81^{a}	1461.25^{b}	1366.59^{c}	1495.27^{a}	4.84
Weight Gain	39.97^{ab}	40.48^{a}	39.83^{ab}	37.17^{b}	40.84^{a}	0.25
Feed Intake (g)	90.28^{b}	99.04^{a}	92.34^{ab}	94.33^{a}	94.69^{a}	1.39
Feed conversion ratio	2.27^{b}	2.45^{ab}	2.32^{ab}	2.54^{a}	2.32^{ab}	0.04
Average Water Intake (ml/bird/day)	269.11^{a}	258.72^{b}	247.14^{c}	255.26^{b}	268.04^{a}	3.00

^{abc} means with different superscripts are significantly ($P < 0.05$) different; *EO* essential oils

Table 3 Relative organ characteristics of broilers on spices essential oils

	Control	Garlic EO	Ginger EO	Tumeric EO	Cinnamon EO	SEM
Relative Carcass weight (%)	67.43^{b}	63.21^{c}	64.30^{c}	70.66^{a}	67.44^{b}	1.56
Head (%)	2.63	2.69	2.77	2.93	2.61	0.07
Shank (%)	5.01	5.10	4.59	5.13	4.65	0.11
Lung (%)	0.59	0.63	0.65	0.68	0.61	0.02
Heart (%)	0.46	0.44	0.44	0.42	0.49	0.01
Liver (%)	1.77	1.90	1.78	1.97	1.97	0.07
Gizzard (%)	1.98	1.86	1.77	2.00	1.83	0.19
Crop (%)	0.58^{b}	0.56^{b}	0.37^{c}	0.73^{a}	0.56^{b}	0.06
Proventriculus (%)	0.43^{ab}	0.32^{b}	0.40^{ab}	0.39^{ab}	0.48^{a}	0.02
Intestine (%)	4.44^{c}	5.98^{a}	5.08^{b}	5.45^{a}	4.63^{c}	0.32
Kidney (%)	0.12^{a}	0.08^{b}	0.08^{b}	0.11^{a}	0.11^{a}	0.01
Gall Bladder (%)	0.11^{ab}	0.10^{ab}	0.09^{b}	0.14^{a}	0.12^{ab}	0.01
Pancrease (%)	0.17	0.15	0.19	0.21	0.22	0.02
Abdominal Fat (%)	1.00^{a}	0.70^{b}	0.69^{b}	0.70^{b}	0.59^{c}	0.06

^{abc} means with different superscripts are significantly ($P < 0.05$) different; *EO* essential oils

lower than those of birds on other treatments. Gall bladder of birds on turmeric EO was significantly ($p < 0.05$) higher than those of birds on ginger EO. Abdominal fat of birds on EOs-based treatments were significantly ($p < 0.05$) lower than birds on control. And the cinnamon group had significantly lower values than the others EO groups.

Serum biochemistry of birds on spices EOs is shown in Table 4. The glucose of birds on garlic EO and ginger EO were significantly ($p < 0.05$) higher than those of birds on other treatments. Total protein of birds on cinnamon EO, turmeric EO, garlic EO and control are statistically ($p > 0.05$) similar and significantly ($p < 0.05$) lower than those of birds on ginger EO. Birds on cinnamon EO and turmeric EO had significantly ($p < 0.05$) lower albumin than those of birds on control, ginger EO and garlic EO which share statistically ($p > 0.05$) similar values. Globulin of birds on ginger EO has significantly highest value across the treatments, while birds on cinnamon EO had significantly higher globulin than birds on turmeric EO and garlic EO. Birds on control had the statistically ($p > 0.05$) least globulin. Cholesterol and alkaline phosphatase of birds on EO-based treatments were statistically ($p > 0.5$) similar and significantly ($p < 0.05$) lower than those of birds on control. Triglyceride of birds on cinnamon EO were statistically similar to those of birds on control and were significantly higher than those of birds on ginger EO. High density lipoprotein of birds on cinnamon EO and garlic EO were statistically ($p > 0.05$) similar to those of birds on control, and were significantly ($p < 0.05$) higher than of birds on ginger EO and turmeric EO. Bilirubin

Table 4 Serum biochemistry of broilers administered spices essential oils

	Control	Garlic EO	Ginger EO	Tumeric EO	Cinnamon EO	SEM
Glucose (mmol/l)	3.86^{b}	5.08^{a}	5.66^{a}	3.15^{b}	3.64^{b}	0.42
Total Protein (g/l)	33.66^{b}	40.32^{b}	73.42^{a}	34.38^{b}	48.47^{b}	9.04
Albumin (g/l)	21.06^{a}	20.13^{a}	20.32^{a}	14.85^{b}	14.38^{b}	2.08
Globulin (g/l)	12.00^{d}	20.19^{c}	53.10^{a}	19.85^{c}	34.09^{b}	2.45
Cholesterol (mmol/l)	0.43^{a}	0.34^{b}	0.34^{b}	0.31^{b}	0.30^{b}	0.03
Triglyceride (mmol/l)	1.92^{a}	1.80^{ab}	1.75^{b}	1.84^{ab}	1.88^{a}	0.06
High density lipoprotein (mmol/l)	3.64^{a}	3.24^{a}	2.95^{b}	2.74^{b}	3.39^{a}	0.21
Bilirubin (mg/dl)	0.38^{b}	0.37^{b}	0.66^{a}	0.46^{b}	0.62^{a}	0.08
Creatinine (mg/dL)	0.25^{b}	0.20^{b}	0.22^{b}	2.42^{a}	0.24^{b}	0.43
Uric Acid (mg/dL)	7.49^{b}	9.11^{a}	8.23^{a}	7.66^{b}	7.48^{b}	0.36
Alkaline phophatase (U/l)	6432.46^{a}	1547.26^{b}	1485.98^{b}	1405.94^{b}	1415.88^{b}	1009.13
Alanine amino transferase (U/I)	31.60	40.11	37.03	32.27	30.23	1.83
Aspartate amino transferase (U/I)	16.80^{c}	35.66^{b}	62.38^{a}	57.89^{a}	58.40^{a}	4.62

^{abcd} means with different superscripts are significantly ($P < 0.05$) different; *EO* essential oils

of birds on cinnamon EO and ginger EO were statistically ($p > 0.05$) similar. Bilirubin of birds on turmeric EO and garlic EO were not significantly ($p > 0.05$) different from those of birds on control, but lower than ginger and cinnamon EO. Creatinine of birds on turmeric EO were significantly ($p < 0.05$) higher than those of birds on other treatment, which share statistically ($p > 0.05$) similar values. Uric acid of birds on garlic EO and ginger EO were significantly ($p < 0.05$) higher than those of birds on other treatment. Alanine amino transferase activity of birds were not influenced by the intake of EOs. Aspartate amino transferase of birds on cinnamon EO, turmeric EO and ginger EO were significantly ($p < 0.05$) higher than those of birds on garlic EO and the significantly ($p < 0.05$) least values were obtained in birds on control.

Metabolic hormones of birds on different spices EOs are shown in Fig. 1. Triiodothyronine of birds were not significantly ($p > 0.05$) affected by the intake of EOs of the different spices. Insulin of birds on EOs were statistically ($p > 0.05$) similar and significantly ($p < 0.05$) lower than those of birds on control.

Adipokines of birds on EOs of different spices is shown in Fig. 2. Adiponectin of birds on cinnamon EO is significantly ($p < 0.05$) higher than those of birds on garlic EO,

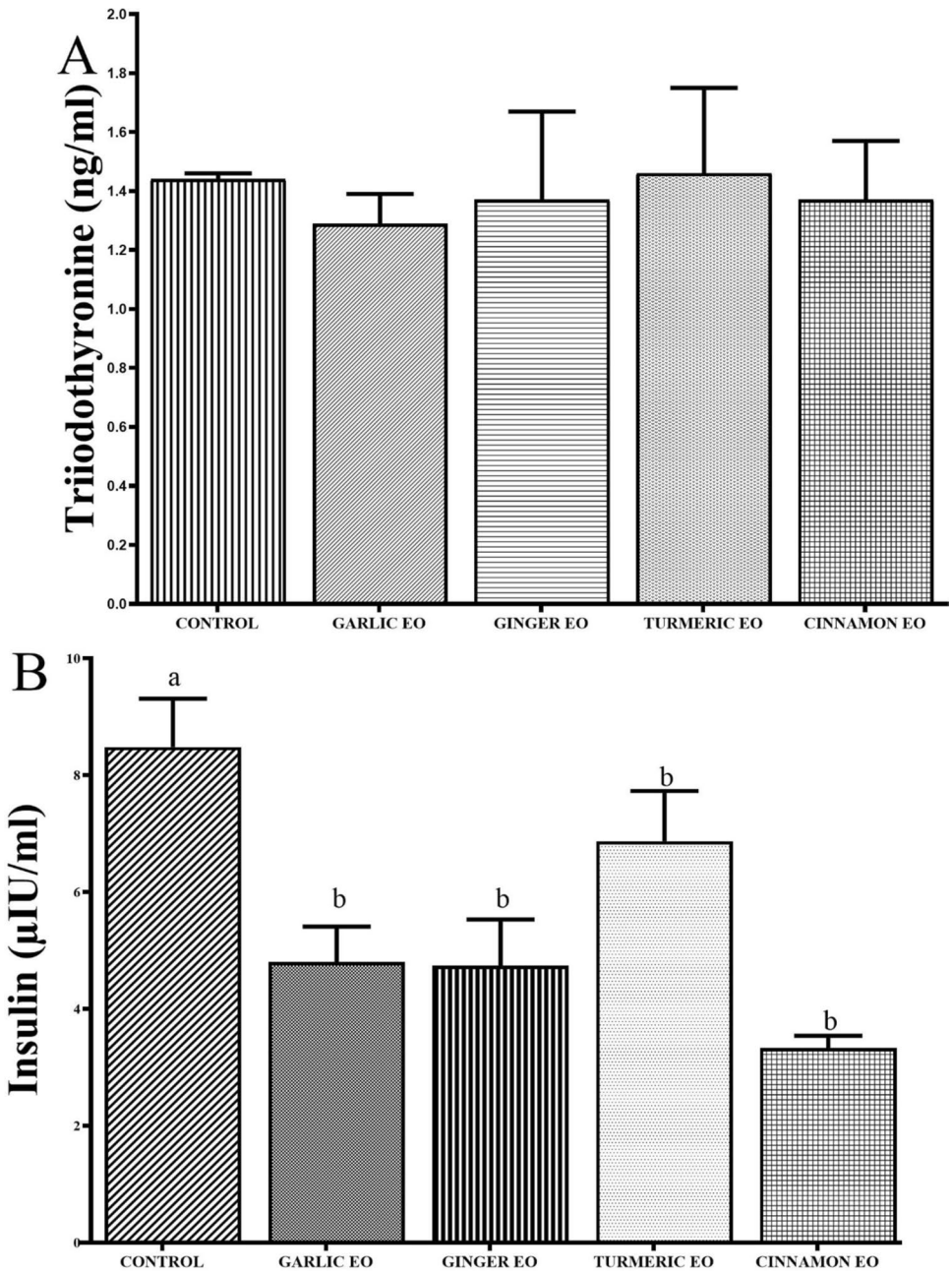


Fig. 1 Metabolic hormones of broiler on spices essential oil. The effects of treatment are shown on **A** Triiodothyronine, **B** Insulin. ab: means with different superscripts are significantly ($P < 0.05$) different: EO: essential oils. Error bar indicates standard error of mean

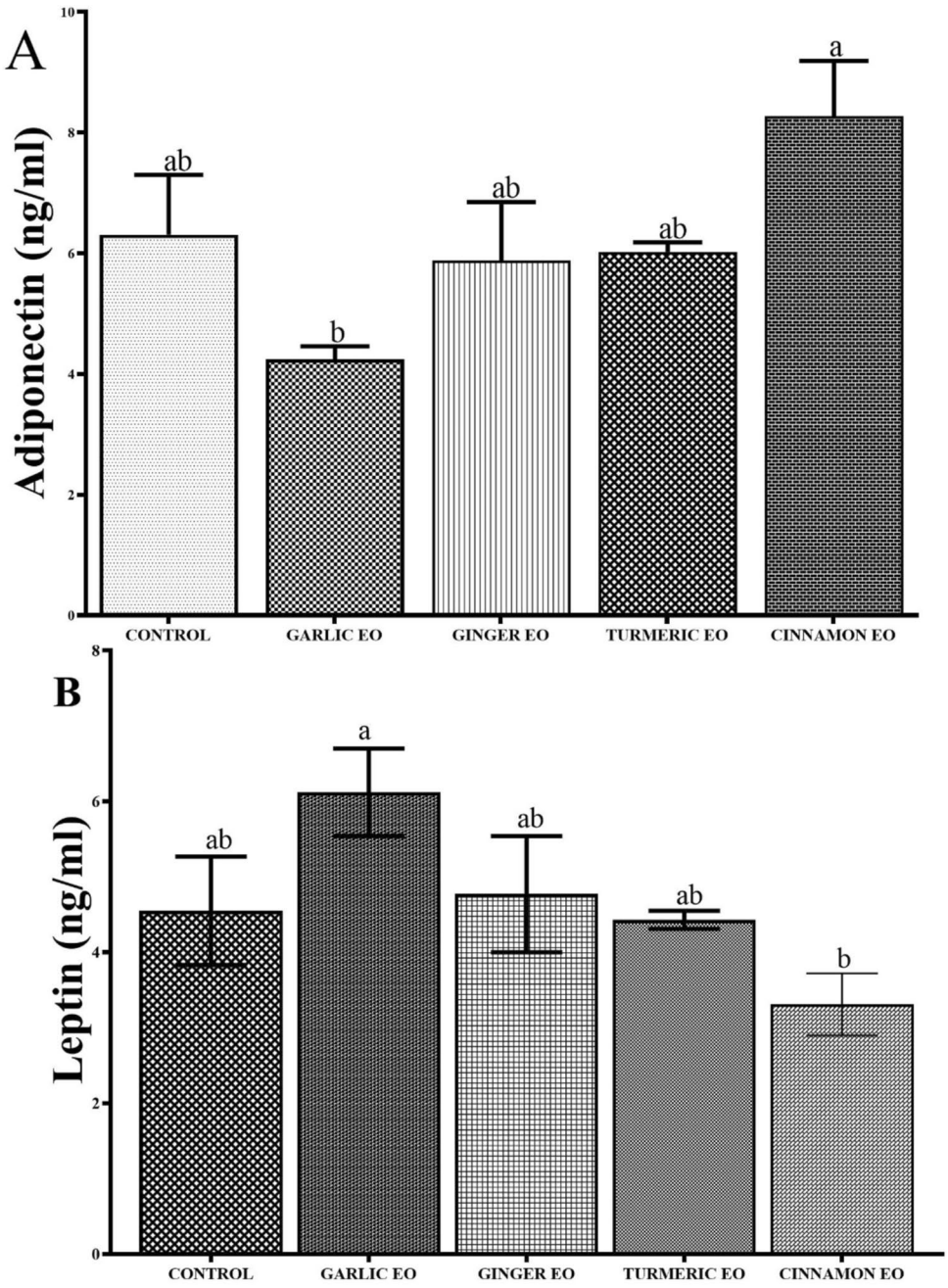


Fig. 2 Adipokines of broiler on spices essential oil. The effects of treatment are shown on **A** Adiponectin, **B** Leptin ab: means with different superscripts are significantly ($P < 0.05$) different; EO: essential oils. Error bar indicates standard error of mean

while birds on turmeric EO, ginger EO and control were not significantly ($p > 0.05$) different from those of other treatment. Leptin of birds on garlic EO was significantly ($p < 0.05$) higher than those of birds on cinnamon EO. However, leptin of birds on turmeric EO, ginger EO and control were not significantly ($p > 0.05$) different from those of other treatment.

Discussion

Beneficial effects of EOs are widely reported on poultry performance and nutrient utilization (Puvaca et al. 2022). This study assessed the role of EOs on leptin, adiponectin and biochemical indices on the growth of broiler chickens. The trend of result obtained revealed that garlic and

cinnamon EO enhance weight gain. This finding is supported by Al-Kassie (2009), who reported that administering cinnamon EOs to broilers improved body weight gain. Furthermore, Abd El-Hack et al. (2020) noted that the enhanced performance of broilers, attributed to the improved immune system, regulated gut microflora, and increased endogenous secretion of digestive enzymes, also resulted in increased antioxidant, antibacterial, and antiviral properties. This is backed by Yang et al. (2019) who claim that cinnamon EO potently acts as natural growth promoters for poultry and reports of Elbaz et al. (2022) claims that addition of lemon and garlic EO singly or as a mixture enhanced productive performance. This support claims by Abd El-Hady et al. (2020) that the addition of an EO mix in broiler chickens oral drench improved physiology and performance. The results of this study are consistent with reports that cinnamon oil improves broiler performance by reducing coliform bacteria in the jejunum and large intestine (Al-Kassie 2010). Additionally, Jamroz and Kamel (2002) and Al-Kassie (2009) found that combinations of EOs from spices led to better performance indices in broilers. Contrary to claims that supplementation of cinnamon oil (500–1000 ppm) had been adjudged not to influence feed consumption and final body weight of broilers (Ciftci et al. 2009).

Reports by Symeon et al. (2014), that supplementing cinnamon oil does not influence performance of broilers, is contrary to the result of this study. Similarly, growth of broilers was not affected by supplementing cinnamaldehyde (Lee et al. 2003), cinnamon powder (Toghyani et al. 2011), EOs of oregano, cinnamon and pepper (Hernandez et al. 2004).

As revealed in this study, Herve et al. (2019) claimed that oral consumption of ginger EO did not influence feed consumption, bodyweight, efficiency of feed utilization in Quails. This suggests that different spices elicit differing growth effects on broilers, just as birds on turmeric EO had the least growth rate in this study.

In this study, all the spices EO stimulated appetite and increased FCR in chickens, agrees with claims that supplementing a blend of pepper + cinnamon + oregano EO enhanced feed efficiency (Garcia et al. 2007). Nemati et al. (2021) reported that ginger possesses many active compounds potent to arouse digestion of feed and digestive enzymes, thereby increasing FI and FCR. However, turmeric, garlic and ginger decreased water intake by the birds possibly due to the taste and smell of the aromatic compound in the EO. However, the EOs were able to stimulate the growth promoting effects in those on garlic EO. As earlier reported, EOs usually affects the taste and smell of supplemented feed or water, leading to enhanced salivary amylase activity and stomach juices while boosting release of digestive secretions (Zhang et al. 2020; Su et al. 2021).

Contrary to claims of Symeon et al. (2014) that cinnamon oil supplementation had no influence on abdominal fat, carcass traits and internal organs weights of chicken. Our study found that EOs from spices reduced abdominal fat, and birds treated with turmeric EO had heavier kidneys, intestines, and gallbladders. The result that garlic and ginger EO enhanced serum glucose, supports claims by Tekeli et al. (2006) that ginger EO increases glucose in broilers. Ginger EO enhanced protein profile, reduced cholesterol profile, possible owing to presence of some active compounds of ginger, adduced to reduce biliary cholesterol reabsorption in the intestine, which modulates lowered cholesterol in hen (Akbarian et al. 2011). It also agrees with Mohd Yusof (2016) that ginger extract stimulated protein synthesis in the cells, suggesting that it may have potential benefits for muscle growth and repair. Herve et al. (2019) noted a decreased cholesterol profile in Japanese quail administered ginger EO. Also, Wang et al. (2011) deduced that consumption of EO of ginger in rats reduced cholesterol, LDL, and triglycerides. Flavonoids and phenolic compounds of EOs are reported to reduce enzyme regulating cholesterol synthesis, which are key enzymes in cholesterol production, thus resulting less fat deposition, more lean yield, decreased cholesterol (Irawan et al. 2021). Although, Abdullah (2012) demonstrated the hypoglycaemic, hypocholesterolemic and hypolipidemic potential of ginger administered to rats, but Qorbanpour et al. (2018) reported no alteration in serum biochemistry of birds administered ginger.

The addition of garlic and lemon EOs has been reported to effectively reduce cholesterol (Elbaz et al. 2022). Result of that all spices EO reduced total cholesterol agrees with Chowdhury et al. (2018) that EO can help to achieve reduction in cholesterol of broiler chickens. This could be due to antioxidants of EOs, altering biosynthesis of cholesterol in favour of change in HDL and LDL (Elbaz et al. 2022). Similarly, cinnamon EO supplementation improved weight gain and feed utilization, and decreased cholesterol in broilers (Al-Kassie 2009). Also as Lu et al. (2013) showed that cinnamon EO can lower cholesterol profile in rats.

This study showed that intake of EOs elevated AST, but did not influence ALT, thus suggesting that these EOs could affect the function of the kidney at this inclusion level. The result of this study, which showed that AST, bilirubin and uric acid of chickens were increased by ginger EO, while ALT, creatinine were not affected compares with Shanoon et al. (2012) that ginger EOs did not influence AST, ALT and creatinine of chicken. And claims of reduced AST and ALT due to ginger EO administration to quails, indicating good liver status. However, higher kidney, and gallbladder weights in birds on turmeric EO coupled with increased serum creatinine and AST suggest a pathological condition impairing elimination of creatinine, an indication of kidney dysfunction induced by the dose of turmeric EO in this study.

Reports by Al-Kassie (2009) and Ciftci et al. (2010) demonstrated that broilers diets supplemented with cinnamon EO decreased serum cholesterol and alanine aminotransferase activity, supports the result obtained in this study. Result of birds on garlic EO, supports claims that addition of EOs in broilers decrease liver enzymes owing to possible to repair liver injury or restoration of cellular permeability often resulting from cytotoxic compounds or via cytoprotection conferred by its phenolic compounds (Elbaz et al.2022).

Although, increased levels of triiodothyronine were reported to affect the performance of chicken, result obtained in this study indicates that triiodothyronine was not influenced by the EOs inclusion. Sadeghi and Moghaddam (2018), reported that thyroid hormones of broilers on medicinal herbs tends to rise. There are reported cases of reducing effect of herbal additives and flavonoids on thyroid function reportedly due to catechin preventing thyroperoxidase and reduction in T3 and T4 (Masoud-Moghaddam et al. 2021). Despite, Jianhua et al. (2000) claims that dietary selenium improves the growth of broilers due to increase in triiodothyronine because Selenium synthesize 50-deiodinase activity, which catalyzes the conversion thyroxine to triiodothyronine. Birds on cinnamon and garlic EO-based groups had better growth rate than the other groups.

In this study, decreased level of insulin was associated with higher serum glucose in birds on garlic and ginger EO-based groups. This could be due to EO, insulin regulation of glucose conversion to fat, to reduce adipose fat accumulation. Insulin can increase cellular intake of glucose and reduce appetite, mostly in chicken of lesser weight (Chuang et al. 2020). As reported by Keita et al. (2013) that the presence of palmitic acid and oleic acid in olive oil lowered serum glucose level by optimizing insulin secretion in pancreas and improving body glucose uptake and utilization.

This study confirmed that garlic EO increased leptin expression, leptin which is a polypeptide hormone has been shown to regulate and maintain normal body weight (Yang et al. 2006). Chuang et al. (2020) explain that leptin inhibits appetite by primarily blocking neuropeptide Y receptors and agouti-related protein, while enhancing the expression of pro-opiomelanocortin and melanocyte-stimulating hormone. This suggests that despite the typical role of leptin in reducing appetite, the observed higher FI and increased leptin levels in birds administered garlic EO might reflect a unique interaction or adaptation that enhances their overall performance. Contrariwise, garlic extract has been associated with suppression or loss of appetite and its oral administration shown to regulate lipid metabolism. This result confirms the expression of leptin by garlic EO and upholds the fact that garlic EO plays a significant role in energy metabolism and body fat regulation. The bioactive compounds in garlic has been found to stimulate gastro-intestinal emptying and facilitate defecation hence protecting the digestive system. (Ben et al. 2014; Shi et al. 2017). Cinnamon EO decreased leptin expression in the serum and the glucose level was not different from the control. The decreased leptin expression could suggest a decreased level of adipose tissue accumulation as increase in leptin expression has been linked to increase in adipose tissue (Frederich et al. 1995). Cinnamon has been associated with slowing down the absorption of sugar from the blood after eating high carbohydrate meal (Nicholas et al. 2019), hence may affect the rate at which energy is produced and expended. This study confirms the influence of cinnamon EO on glucose regulation, as well as energy metabolism through leptin expression activities. Cinnamon significantly increased the expression of adiponectin in the birds. White adipose tissue (WAT) acts as energy storage vat and is the keystone of energy homeostasis (Choe et al. 2016). WAT has endocrine function in synthesizing and releasing proteins and which adiponectin as a type of adipokine has been directly or indirectly linked to obesity or having excess adipose tissue. This would account for better growth rate associated with birds on cinnamon EO in this study. Broiler birds are a valuable model for studying adiponectin expression. Typically, increased body fat (WAT) storage is associated with lower levels of adiponectin, which is linked to various metabolic diseases and elevated abdominal fat (Resnyk et al. 2013). However, the observed trend in our study shows low serum glucose and abdominal fat despite a high growth rate in birds consuming cinnamon EO, which also had higher adiponectin levels and reduced leptin. This apparent contradiction suggests that cinnamon EO may positively influence energy metabolism and promote metabolic homeostasis, potentially mitigating the typical negative association between adiponectin levels and body fat.et al. Conversely, birds administered garlic EO exhibited higher leptin levels and lower adiponectin levels, yet they also showed a high growth rate and reduced abdominal fat compared to the control group. This suggests that garlic EO may influence metabolic regulation to decrease adipose fat accumulation while promoting lean meat yield. Leptin, which is known to induce satiety and regulate energy consumption, has its activity decreased by glucagon and enhanced by insulin (Zhao et al. 2012). This indicates that the observed effects could be due to alterations in leptin and insulin signaling pathways. Corroborating the trends of the results of this study are claims that leptin promotes the chicken growth hormone gene expression, which in turn promotes adipose metabolism and muscle building and reduces glucose and triglycerides, and increases FI of chickens (Chuang et al. 2020). Herbs and EOs influence the trends of adipose metabolism and performance in birds, hence reducing adipose fat deposition without reducing feed utilisation is a challenge facing poultry (Chuang et al. 2020), and this was addressed by garlic and cinnamon EO in this study.

Conclusion

This study reveals that cinnamon and garlic EOs have superior growth promoting effects than turmeric and ginger EOs due to their regulatory effects on metabolic hormones and energy metabolism. Water intake was highest with cinnamon EO and control, and lowest with ginger EO. Turmeric EO improved carcass weight. EOs affected serum biochemistry, with garlic and ginger influencing higher glucose, and cinnamon EO improving HDL levels and elicited the highest adiponectin. Overall, specific EOs positively impact broiler performance and health. Hence, 30 ml/L of cinnamon and garlic EOs administration in chicken are potent phytogenic oral supplements to promote growth and lean yield in broiler chicken, showing superior benefits over turmeric and ginger EOs.

Abbreviations EO: Essential oils; LDL: Low density lipoprotein; ALT: Alanine amino transferase; AST: Aspartate amino transferase; HDL: High density lipoprotein; T3: Triiodothyronine; FI: Feed intake; FCR: Feed conversion ratio; WAT: White adipose tissue

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Data availability The dataset used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethical approval and consent to participate The authors confirm that the ethical policies of the journal as noted on the journal's author guidelines page have been adhered to and the institutional ethics committee for care and use of animal for research approved the study (approval no:- AP/REC/2021/004). The authors confirm that they have followed EU standards for the protection of animals used for scientific purposes.

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