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Growth performance, carcass attributes, blood hematology and biochemical constituents of growing rabbits supplemented with cinnamon and clove powder

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A two-way experimental design, comprising a total of 180 growing commercial cross-bred 30-day-old rabbits were assigned to five groups (36 kits in each group equally distributed between the sexes, with twelve replicates of 3 rabbits) was adopted to investigate the effects of dietary treatment (cinnamon and cloves supplemented at 150 and 250 mg/kg diet each) and sex on rabbit growth performance, carcass characteristics, hematological and biochemical indices. The first group was given a basal diet with no supplements as the control, the second and third groups were given cinnamon at 150 and 250 mg/kg diet, respectively. In turn, the fourth and fifth groups were administered cloves at 150 and 250 mg/kg diet, respectively. Treatment with cinnamon and clove powder supplements significantly increased live body weight (LBW), live body weight gain (LBWG) and feed consumption (FC). Also, it significantly increased red blood cell count (RBC), white blood cell count (WBC), plasma total protein, albumin and globulin levels. The treatment with both supplements led to a significant decrease in feed conversion ratio (FCR), as well as levels of glucose, cholesterol, triglycerides, aspartate aminotransferase (AST) and alanine aminotransferase (ALT). Rabbits fed 250 mg cinnamon/kg diet had the highest LBW, LBWG, FC, dressing percentage, meatiness and plasma total protein, but had lowest levels of glucose, cholesterol, triglycerides, AST and ALT compared to the other groups. It was concluded that cinnamon supplement at 250 mg /kg diet may be an effective method to improve growth, carcass characteristics and health in both sexes of growing rabbits thanks to its advantageous effect on blood picture and biochemical constituents and consequently may be the primary factor promoting abundant production.

KEY WORDS: carcass / cinnamon / cloves / hematology / rabbits

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Plant-derived substances known as phytogenic feed additives, phytobiotics or botanicals are used in animal feed to improve livestock performance by enhancing feed quality and increasing production output [Windisch *et al.* 2008, Steiner 2009]. As part of the global campaign to get back to nature, the World Health Organization [WHO 2002] supports the use of medicinal herbs and plants to replace or limit the use of chemicals. Herbs may give advantages such as increased feed intake and appetite, antiviral, antibacterial, and antioxidant activities, immune response activity, and stimulation of endogenous digestive enzyme production [Windisch *et al*. 2008, Dalle Zotte *et al*. 2016].

The livestock industry has encountered increasing hurdles since the use of antibiotics as growth enhancers was prohibited. As a result, phytogenic sources are regarded as a risk-free option. They are naturally occurring bioactive compounds that have a positive impact on animal health and development. These natural feed additives are widely accepted as safe. Many nutritional strategies, on the other hand, might be investigated in order to find particular beneficial outcomes, such as enhanced feed utilization and gut health in farm animals [Skoufos *et al.* 2020]. Many studies have established the applicability of phytogenic feed additives as growth promoters because these additives have an active role in rabbit productivity [Attia *et al*. 2019ab, Abedo *et al.* 2020, Abou-Kassem *et al.* 2021].

Cinnamon (*Cinnamomum zeylanicum*) is one of the world's oldest spices. Contents of cinnamaldehyde (71.64%) and eugenol (6.53%) are higher, while that of coumarin (2.48%) is lower in real cinnamon bark powder. Furthermore, it contains a high quantity of total phenolic components, amounting to 73.26 mg gallic acid equivalent/g sample, as well as total flavonoids at 45.07 mg catechin equivalent per 1 g of sample [Lopes *et al.* 2022]. Other minor components include eugenol, o-methoxycinnamaldehyde, monoterpenoids and trans-cinnamic acid. Cinnamon bark also contains polysaccharides, phenylpropanoids, diterpenes, mucilage and procyanidins [Charles 2013]. The presence of these compounds may increase various bioactivities of cinnamon. In studies on rabbits cinnamon has been found to lower triglyceride and total cholesterol levels [El-Nomeary *et al.* 2020]. It has various health benefits, such as lowering blood glucose levels in rabbits [Khalse *et al.* 2013].

In turn, cloves are aromatic dried flower buds of a Myrtaceae tree *Syzygium aromaticum* (also known as *Eugenia aromaticum*). Cloves are rich in essential oils at 15-20% [Idowu *et al.* 2021], with e*ugenol*, the key bioactive component of cloves [Neveu *et al.* 2010] accounting for is 70-85% [Cortés-Rojas *et al.* 2014], with caryophyllene (5-12%) and eugenol acetate (10-15%) also present [Mittal *et al*. 2014]. Cloves contain high concentrations of phenolic components such as phenolic acid, flavonoids, hydroxyphenyl propane, hydroxycinnamic acid and hydroxybenzoic acids [Adefegha *et al*. 2016]. They also have a significant quantity of total flavonoids at 125.4 mg quercetin equivalent per 1 g of extract and total phenolic compounds at 207.6 mg tannic acid equivalent per 1 g of extract [de Lima *et al*. 2021]. The content of these phenolic compounds may enhance many bioactivities of cloves [Ryu *et al.*

2016]. Clove oil may be an effective supplement found to improve the lipid profile in quails [Hussein *et al*. 2019], while it is also an excellent antioxidant and antibacterial agent [Franz *et al*. 2020].

Cinnamon (*Cinnamomum zeylonicum*) and cloves (*Syzygium aromaticum*) are two spices known for their appetite boosting properties [Dalle Zotte *et al.* 2016].

The primary aim of this study was to investigate the impact of adding cinnamon and clove powder at two different levels to the diet of growing rabbits from 30 to 72 days of age on rabbit growth, carcass characteristics, blood haematology and plasma constituents. It was attempted to explain why cinnamon and cloves improve the productive performance and health of growing rabbits by focusing on the hypothesis that cinnamon and cloves, as phytonutrients, have a positive effect on blood parameters. The impact of sex on the examined variables was also investigated.

Material and methods

Animal care and maintenance were carried out in accordance with the recommendations of the Egyptian research ethics committee.

Experimental design and housing

In this study 180 growing commercial cross-bred rabbits (90 females and 90 males) were included in the experiment as 30-day-old kits and were maintained in flat-deck cages. The kits were divided into five groups (36 rabbits in each group equally distributed between the sexes, with twelve replicates of three rabbits). The temperature in the house was 18±2°C during the experiment, while relative humidity ranged between 60 and 70%. Rabbits were identified by ear bands and allocated to the experimental groups where each cage housed the same sex. The first group was given a basal diet without supplements as a monitoring group, while the 2nd and 3rd groups were given cloves supplement at 150 and 250 mg per kilogram of basal diet, respectively, while the 4th and 5th groups were given cinnamon at 150 and 250 mg per kilogram of basal diet, respectively.

Experimental diets

Trial diets were designed to cover the nutritional demands of growing rabbits, according to de Blas and Mateos [2020]. A pelleted diet and water were provided *ad libitum* throughout the study from the 30th to 72nd day of age. The composition of the ingredients is shown in Table 1.

Preparation of raw phytogenic ingredients

Cinnamon bark and clove buds were bought from a local store of traditional medicinal herbs and validated at the Department of Botany, the Faculty of Agriculture, Fayoum University, Egypt. Previous purchases came in the dry form and were ground using an electric grinder at room temperature before being added to the diet variants in the specified amounts. These levels were determined based on the results of analyses

Table 1. Ingredients and computed contents of experiment diets (g/kg as-fed basis, except where otherwise stated)

Ingredients		Calculated chemical analysis**	g/kg
Alfalfa hay	300	Dry matter	902
Wheat bran	320	Organic matter	824
Barley grain	190	Nitrogen-free extract	590
Soybean meal 44%	140	Neutral detergent fiber	282
Molasses	30.0	Digestible energy (MJ/Kg)	10.5
Limestone	13.0	Acid detergent fiber	171
Premix*	3.00	Crude fiber	130
Sodium chloride	3.00	Ether extract	23
Anti-coccids	1.00	Crude protein	178
Total	1000	Ash	78.6
		Phosphors	5.6
		Calcium	8.8
		Methionine	3.2
		Lysine	9.0
		Arginine	10.4
		Methionine + Cysteine	5.7

*The premix contains the following ingredients in 3 kg: Vit K_3 (Menadione sodium bisulfite complex), 2000 mg; Vit E (all-rac-α-Tocopheryl acetate), 40000 mg; Vit D_3 (Cholecalciferol), 22500 µg; Vit A (trans-retinyl acetate), 1800000 µg, Vit B_7 (Biotin), 50 mg; Vit B_2 (Riboflavin), 4000 mg; Vit B_1 (Thiamine), 2000 mg; Vit B_4 (choline chloride), 25000 mg; Vit B_6 (pyridoxamine), 2000 mg; Vit B_5 (Pantothenic acid; (D-calcium pantothenate), 1000 mg; Vit B_3 (nicotinic acid), 50000 mg; Vit B_{12} (Cyanocobalamin),10 mg; Vit B_9 (Folic acid), 3000 mg; Iron ($FeSO_4$), 5000 mg; Zinc (ZnO), 50000 mg; Manganese (MnO), 8500 mg; Selenium (Na_2SeO_3), 100 mg; Iodine (CaI), 200 mg; Copper ($CuSO_4 \cdot 5H_2O$), 500 mg; Cobalt ($Co(SO_4)_2 \cdot 6H_2O$), 100 mg and calcium carbonate to get the total weight to 3.0 Kg.
**The calculated chemical composition of the basal diet determined according to FEDNA [2019]; MJ/kg = Megajoule/Kilogram.

for cinnamon [Adisakwattana *et al*. 2011, Charles 2013] and cloves, respectively [Nurdjannah and Bermawie 2012, Lim 2014]. The supplements were added to very small amounts of feed components (as premix), then to molasses and subsequently they were added to wheat bran, which was blended with the rest of the ingredients and pelleted on the farm in a small feed pellet machine.

Experimental measurements

Throughout the trial live body weight (LBW; kg) was measured weekly and an average live body weight gain (LBWG; kg) was computed. Throughout the trial at weekly intervals the feed consumption (FC; kg) was properly recorded in grams and a total FC was computed at the end of the experiment. Feed remnants (feed refuse) from each cage were considered when determining FC and feed conversion ratio (FCR).

Characteristics of slaughtering and carcass

On the 72nd day ninety rabbits were collected at 18 rabbits from each group (nine males and nine females selected as closest to the mean LBW of each replicate) and slaughtered after fasting for about 12 hours with *ad libitum* access to water. The animals

were weighed individually and slaughtered instantly. The weights of the head, heart, liver, spleen, lung, perirenal fat and scapular fat were computed as a percentage of the pre-slaughter weight. The carcass was separated into four sections: the hind pieces (hind leg, rump and shank), the loin pieces (belly, hip and loin), the front pieces (front leg and neck), and the thoracic cage pieces (rib and shoulder). Chemical meat tests were performed on a dry matter percentage basis in accordance with [AOAC 2005].

Blood samples

During the slaughter of rabbits 90 blood samples were taken (18 samples from each group equally between the sexes), with EDTA used as an anticoagulant for hematological traits and to obtain plasma. Plasma samples were produced by centrifuging the samples for 20 minutes at 4000 rpm and they were kept at -20 °C.

Haematology parameters

Hemoglobin (g/L), hematocrit and red blood cell count (RBC, $X10^{12}$/L) were determined according to Van Kampen and Zillstra [1983], Harvey [2012], and Smock [2019], respectively. Furthermore, mean corpuscular volume (MCV, fL), mean corpuscular haemoglobin (MCH, pg/cell) and mean corpuscular haemoglobin concentration (MCHC, g/L) were calculated using RBC, hematocrit and haemoglobin counts [Smock 2019], respectively. Total white blood cell concentration (WBC, $X10^{9}$/L) and differential WBC were determined using a hemocytometer according to Voigt and Swist [2011] and Harvey [2012], respectively.

Constituents of plasma

Total protein, albumin, glucose, total cholesterol, triglycerides, aspartate aminotransferase (AST) and alanine aminotransferase (ALT) were all measured in stored plasma samples. Globulin was determined by subtracting total protein from albumin. The immune index (albumin/globulin) and neutrophils/lymphocytes were calculated as immune system markers. Colorimetric analysis of plasma biochemistry samples was carried out according to the manufacturer's instructions using standard kits from (Bio-diagnostic, Cairo, Egypt).

Statistical analysis

Each cage housed three rabbits within all treatments and served as the experimental unit for feed consumption and feed conversion ratio, whereas the rabbit was the experimental unit within each treatment for the other parameters. Two-way analyses of variance were conducted with treatment and sex as the main effects:

$$y_{ijk}=\mu+ T_i + S_j+ (TS)_{ij} + e_{ijk}$$

where:

y_{ijk} – observation of the l^{th} individual in the i^{th} treatment and the j^{th} sex;

μ – overall mean;

T_i – fixed effect of i-th treatment (**i**= 1, 2, …5);

S_j – fixed effect of sex (*j*= 1, 2);

$(TL)_{ij}$ – fixed effect of the treatment x sex interaction;

e_{ijk} – random error term.

Tukey's test was applied to detect differences in treatment means. The following variables were evaluated using the SPSS software's General Linear Models approach [SPSS 2008].

Results and discussion

Treatment effects on live body weight at 72 days of age (LBW_{72}) and live body weight gain ($LBWG_{30-72}$) were significant (p=0.041, 0.022, respectively), as were feed consumption (FC_{30-72}) and feed conversion ratio (FCR_{30-72}) from 30 to 72 days of age (p=0.013, 0.011, respectively). With the exception of FCR_{30-72}, rabbits fed 250 mg cinnamon/kg diet were better in all the previous characteristics. However, FCR_{30-72} levels were highest in rabbits given the 250 mg cloves/kg diet, followed by rabbits fed the 150 mg cloves/kg diet. Males showed significantly higher $LBWG_{30-72}$ and FC_{30-72} than females, but the lowest FCR_{30-72}, as seen in Table 2. The treatment x sex interaction was significant (p=0.0112) for LBW_{72} and (p=0.0121) for FCR_{30-72}, while it was also significant (p=0.0520) for $LBWG_{30-72}$ and (p=0.0212) for FC_{30-72}.

Table 2. Means and standard deviations (in parentheses) of rabbit growth and feed traits as a result of cinnamon and clove supplements, sex and treatment x sex interaction

Item	Growth and feed traits				
	LBW_{30} (kg)	LBW_{72} (kg)	$LBWG_{30-72}$ (kg)	FC_{30-72} (kg)	FCR_{30-72}
Treatment					
control	0.63 (0.07)	1.79^{c} (0.09)	1.16^{b} (0.05)	4.41^{c} (0.26)	3.80^{a} (0.18)
cinnamon 150 mg kg	0.63 (0.09)	1.93^{b} (0.12)	1.32^{a} (0.07)	4.62^{ab} (0.21)	3.51^{b} (0.20)
cinnamon 250 mg kg	0.63 (0.12)	1.99^{a}(0.11)	1.36^{a} (0.07)	4.78^{a} (0.19)	3.52^{b} (0.15)
clove 150 mg kg	0.63 (0.12)	1.89^{b} (0.12)	1.31^{a} (0.05)	4.58^{b} (0.20)	3.48^{c} (0.17)
clove 250 mg kg	0.63 (0.10)	1.95^{ab} (0.12)	1.32^{a} (0.06)	4.56^{b} (0.20)	3.47^{c} (0.20)
Sex					
♂	0.63 (0.08)	0.63 (0.11)	1.93 (0.05)	4.75^{a} (0.20)	3.67 (0.17)
♀	0.63 (0.08)	0.63 (0.10)	1.90 (0.06)	4.36^{b} (0.20)	3.53 (0.19)
SEM	0.01	0.01	0.02	0.02	0.02
p-value					
T	0.99	0.04	0.02	0.01	0.01
S	0.97	0.87	0.05	0.03	0.04
T x S	0.23	0.01	0.05	0.02	0.01

^{abc}Means within each effect in the same column having different superscripts are significantly different at P≤0.05. LBW_{30} – live body weight at 30 days of age; LBW_{72} – live body weight at 72 days of age; $LBWG_{30-72}$ – live body weight gain from 30 to 72 days of age; FC_{30-72} – feed consumption from 30 to 72 days of age; FCR_{30-72} – feed conversion ratio from 30 to 72 days of age; SEM – standard error of the mean; T – treatment; S – sex; T x S – treatment x sex interaction effects.

Rabbits given 250 mg cinnamon/kg of diet had significantly increased eviscerated weight, dressing percentage, meatiness percentage and lung percentage while having

Table 3. Means and standard deviations (in parentheses) of rabbit carcass traits as a result of cinnamon and clove supplements, sex and treatment x sex interaction

Item	Control	Treatment				Sex		*p*-value		
		cinnamon		cloves						
		150 mg/kg	250 mg/kg	150 mg/kg	250 mg/kg	♂	♀	T	S	T x S
Carcass parameters										
evisc wt (kg)	0.937^{c} (0.09)	1.14^{a} (0.09)	1.19^{a} (0.09)	0.973^{c} (0.09)	1.01^{bc} (0.09)	1.07 (0.09)	1.02 (0.09)	0.01	0.01	0.05
dressing (%)	42.2^{c} (2.55)	46.6^{b} (0.62)	48.7^{a} (0.80)	45.8^{b}(1.78)	46.4^{b}(1.07)	43.6 (1.30)	45.4 (1.35)	0.01	0.01	0.01
meatiness (%)	39.5^{d} (0.93)	43.8^{ab} (1.06)	44.4^{a} (2.95)	42.4^{c} (3.06)	43.4^{b} (3.92)	42.6 (2.40)	41.0 (2.35)	0.05	0.01	0.01
head (%)	6.23^{d} (0.87)	7.67^{a} (0.83)	7.43^{ab} (0.81)	6.86^{bc} (0.93)	6.54^{c} (0.90)	7.27 (0.90)	6.42 (0.83)	0.02	0.02	0.05
lung (%)	0.64^{b} (0.07)	0.68^{ab} (0.08)	0.72^{a} (0.08)	0.69^{a} (0.07)	0.71^{a} (0.07)	0.64 (0.07)	0.63 (0.07)	0.05	0.68	0.21
liver (%)	3.44^{c} (0.30)	3.56^{b} (0.58)	3.61^{a} (0.24)	3.62^{a} (0.61)	3.55^{b} (0.86)	3.39 (0.55)	3.79 (0.51)	0.05	0.04	0.05
heart (%)	0.82^{c} (0.02)	0.97^{ab} (0.04)	1.01^{a} (0.04)	0.86^{bc} (0.04)	0.91^{b} (0.05)	1.02 (0.04)	0.99 (0.04)	0.03	0.14	0.47
PF (%)	2.19^{a} (0.58)	1.30^{b} (0.22)	1.28^{b} (0.52)	1.33^{b} (0.08)	1.29^{b} (0.37)	1.98 (0.37)	2.64 (0.37)	0.02	0.01	0.02
SF (%)	2.74^{a} (0.73)	1.25^{d} (0.56)	1.13^{e} (0.62)	1.59^{b} (0.71)	1.42^{c} (0.78)	2.91 (0.65)	1.43 (0.65)	0.02	0.05	0.02
Carcass cuts										
FPW (%)	21.7 (3.47)	21.8 (2.17)	20.9 (2.97)	21.0 (2.45)	21.6 (3.13)	21.9 (2.91)	21.9 (2.91)	0.19	0.48	0.05
TCW (%)	18.0 (2.07)	18.1 (2.10)	18.4 (2.18)	18.4 (1.97)	19.0 (1.83)	18.0 (1.77)	18.0 (1.77)	0.76	0.27	0.05
LW (%)	28.4 (3.23)	28.1 (2.79)	28.3 (3.47)	28.3 (2.56)	27.4 (2.84)	28.4 (2.96)	28.5 (3.05)	0.90	0.24	0.05
HPW (%)	31.9 (4.14)	32.0 (5.03)	32.4 (4.23)	32.3 (1.97)	32.0 (1.49)	31.7 (3.22)	31.6 (3.20)	0.53	0.34	0.05
Chemical analysis										
moisture (%)	72.8 (0.92)	73.0 (0.57)	72.9 (1.33)	72.5 (0.58)	72.8 (0.57)	72.9 (0.65)	72.6 (0.65)	0.88	0.35	0.63
ash (%)	1.37 (0.21)	1.23 (0.86)	1.38 (0.21)	1.39 (0.25)	1.37 (0.09)	1.28 (0.34)	1.34 (0.34)	0.56	0.28	0.35
protein (%)	21.4 (0.27)	21.8 (0.71)	21.8 (0.19)	21.5 (0.81)	21.6 (0.69)	21.5 (0.61)	21.4 (0.62)	0.52	0.65	0.71
ether extract (%)	3.24 (0.63)	3.07 (0.55)	3.03 (0.33)	3.23 (0.57)	3.10 (0.29)	3.23 (0.43)	3.25 (0.43)	0. 98	0.76	0.87

^{abcd}Means within each effect in the same row having different superscripts are significantly different at P≤0.05.

T – treatment; S – sex; T x S – effects of treatment x sex interaction; Evisc. Wt – eviscerated weight; PF= perirenal fat (%), SF – scapular fat (%); FPW– fore pieces weight (front leg and neck); TCW – thoracic cage pieces weight (rib and shoulder);; LW – loin pieces weight (belly, hip and loin); HPW – hind pieces weight (hind leg, rump and shank).

the lowest perirenal fat percentage and scapular fat percentage. However, rabbits fed 150 mg cloves/kg of diet had a greater liver percentage. Furthermore, the control group rabbits exhibited larger perirenal and scapular fat percentages (Tab. 3).

Furthermore, males exhibited greater eviscerated weight, meatiness percentage, head percentage and scapular fat percentage than females. On the other hand, females showed significantly higher dressing percentages, liver percentages and perirenal fat percentages. On the other hand, the effects of treatment and sex on carcass cuts and chemical analysis were non-significant, as shown in Table 3. However, the treatment x sex interaction had a significant ($p \leq 0.01$) effect on dressing percentage, meatiness, perirenal fat and scapular fat, as well as a significant ($p \leq 0.05$) influence on eviscerated weight, head, liver and carcass cuts (fore part weight, thoracic cage weight, loin weight and hind part weight).

The dietary treatment had a significant ($p=0.05$) effect on RBC, MCV, MCH and WBC in rabbits fed 250 mg cloves/kg of diet, as well as a highly significant ($p=0.01$) effect on levels of neutrophils, lymphocytes, neutrophils/lymphocytes, segmented neutrophils and stab neutrophils in rabbits fed 250 mg cinnamon/kg of diet (Tab. 4).

The addition of either of these two natural feed additives to the rabbit diets had no significant influence on blood haemoglobin, hematocrit, MCHC, basophil, eosinophil or monocyte levels, which were comparable to those in the control group.

As exhibited in Table 4, the sex and treatment x sex interactions had no influence on blood hematological indices.

The treatment caused a significant ($p \leq 0.01$) reduction in plasma albumin/globulin, glucose, total cholesterol, triglycerides, AST, and ALT levels, while significantly increasing plasma total protein, albumin, and globulin contents ($p \leq 0.01$). Rabbits fed 250 mg cinnamon/kg of diet showed increased levels of plasma total protein, albumin and globulin, but decreased levels of plasma glucose, total cholesterol, triglycerides, AST and ALT (Tab. 5).

Males had significantly ($p \leq 0.05$) greater plasma total protein levels and also a greater immune index than females.

As shown in Table 5, sex had a non-significant ($p > 0.05$) influence on other plasma components. In turn, the treatment x sex interaction had a significant ($p \leq 0.05$) effect on plasma albumin/globulin, total cholesterol, triglycerides and ALT.

Males consuming 150 and 250 mg cinnamon/kg of diet, as well as males supplied 150 mg cloves/kg of diet, females given 250 mg cloves/kg of diet and females fed 250 mg cinnamon/kg of diet had higher LBW72 of 2013, 2009, 2004 and 2003, respectively, than the other groups (Tab. 6). The $FCR_{30\text{-}72}$ was better in females and males given 150 and 250 mg cloves and cinnamon/kg of diet, respectively. In this order, males provided 250 mg cinnamon/kg of diet showed the greatest $FC_{30\text{-}72}$, followed by males fed 150 mg cinnamon/kg diet, males fed 150 mg cloves/kg of diet and males fed 250 mg cloves/kg of diet.

Females given 250 mg cinnamon/kg of diet had higher eviscerated weight followed by males fed 150 mg cinnamon/kg of diet. Females given 250 and 150 mg

Table 4. Means and standard deviations (in parentheses) of rabbit hematological traits, hematimetric indices, white blood cell counts and differentiated percentage in response to cinnamon and clove supplements, sex and treatment x sex interaction

Item	Control	Treatment				Sex		*p*-value		
		cinnamon		cloves						
		150 mg/kg	250 mg/kg	150 mg/kg	250 mg/kg	♂	♀	T	S	T x S
Hematological traits										
Hb, g/L	123 (2.50)	123 (2.16)	124 (2.63)	124 (2.16)	125 (1.71)	124 (2.16)	124 (2.16)	0.24	0.89	0.33
HCT	0.40 (0.01)	0.40 (0.01)	0.41 (0.01)	0.40 (0.01)	0.40 (0.01)	0.40 (0.01)	0.40 (0.01)	0.37	0.27	0.65
RBCs $X10^{12}$/L	2.97^{d} (0.08)	3.03^{cd} (0.11)	4.97^{b} (0.09)	4.11^{bc} (0.03)	5.88^{a} (0.08)	4.97 (0.8)	4.37(0.07)	0.05	0.39	0.13
Hematimetric indices										
MCV (fL)	134^{a} (1.71)	132^{a} (2.27)	81.6^{b} (1.89)	98.0^{b} (2.40)	68.6^{c} (1.78)	81.2 (1.99)	91.8 (1.99)	0.05	0.23	0.26
MCH (pg/cell)	41.3^{a} (1.14)	40.7^{a} (1.41)	25.0^{bc} (1.54)	30.1^{b} (1.13)	21.2^{c} (1.10)	24.9 (1.24)	28.3 (1.27)	0.05	0.18	0.13
MCHC (g/L)	308 (15.2)	307 (15.2)	306 (15.2)	307 (15.2)	309 (15.2)	307 (15.2)	309 (15.2)	0.94	0.24	0.82
White blood cell count and differentiated percentage										
WBCs $X10^{9}$/L	9.90^{d} (0.71)	10.9^{cd} (0.83)	11.1^{bc}(0.94)	11.9^{b} (0.94)	12.4^{a} (1.11)	11.4 (0.94)	11.0 (0.94)	0.05	0.75	0.18
Neut (%)	42.9^{a} (5.20)	29.9^{cd} (3.59)	26.5^{d} (5.97)	33.2^{bc} (2.50)	35.2^{b} (3.30)	43.6 (3.85)	44.4 (3.78)	0.01	0.21	0.84
Lymph (%)	49.1^{c} (5.20)	62.3^{a} (3.59)	64.8^{a} (5.85)	58.4^{ab} (2.50)	56.7^{b} (3.30)	50.0 (3.85)	49.3 (3.78)	0.01	0.28	0.67
Neut / Lymph	0.87^{a} (0.21)	0.48^{cd} (0.14)	0.41^{d} (0.26)	0.57^{b} (0.10)	0.62^{b} (0.16)	0.87 (0.15)	0.90 (0.15)	0.01	0.32	0.28
Baso (%)	1.02 (0.08)	1.05 (0.08)	1.42 (0.08)	1.26 (0.08)	1.29 (0.08)	1.19 (0.08)	1.18 (0.08)	0.83	0.24	0.94
Eosin (%)	3.65 (0.91)	3.53 (0.81)	3.91 (0.85)	3.78 (0.81)	3.57 (0.78)	2.07 (0.71)	2.13 (0.71)	0.94	0.24	0.30
Mono (%)	3.35 (0.59)	3.21 (0.59)	3.36 (0.59)	3.39 (0.59)	3.25 (0.59)	3.10 (0.59)	3.00 (0.59)	0.56	0.37	0.44
Neutrophil components										
SegNeut (%)	40.5^{a} (5.80)	28.3^{c} (3.40)	24.8^{c} (5.38)	31.3^{bc} (2.08)	33.3^{b} (2.75)	41.6 (3.87)	42.3 (3.87)	0.01	0.21	0.37
StaNeut (%)	2.36^{a} (0.82)	1.70^{cd} (0.58)	1.67^{d} (1.26)	1.91^{b} (0.50)	1.88^{b} (0.58)	2.05 (0.66)	2.07 (0.66)	0.01	0.21	0.38

[abcd]Means within each effect in the same row having different superscripts are significantly different at P≤0.05.

T – treatment**;** S – sex; T x S – effects of treatment x sex interaction; Hb – hemoglobin; HCT – hematocrit; RBC – red blood cell count; MCV – mean corpuscular volume; MCH – mean corpuscular hemoglobin; MCHC – mean corpuscular hemoglobin concentration; WBC – white blood cells count; Neut – neutrophil; Lymph v lymphocyte; Baso – basophil; Eosin – eosinophil; Mono – monocyte; SegNeut – segmented neutrophil; StaNeut – staff (stabs or bands) neutrophil.

cloves or cinnamon/kg diet had the greatest dressing percentage, followed by males of each treatment at their respective levels. Females provided 250 mg cloves/kg diet showed the greatest dressing percentage compared to the other interaction groups, whereas females fed 250 mg cinnamon/kg diet had the highest meatiness percentage. Males and females fed 250 and 150 mg cinnamon/kg diet had the greatest head percentage of any interaction group. There was no discernible trend in liver percentage. Males and females fed 250 and 150 mg cinnamon or cloves/kg diets presented a reduction in perineal and scapular fat contents (Tab. 6).

Females fed 150 mg cloves/kg diet had the smallest fore part weight, whereas in females fed 250 or 150 mg cinnamon/kg diet it was the highest. Males fed 150 or 250 mg cinnamon/kg diet, as well as females received 150 mg cinnamon/kg diet had the greatest thoracic cage weight, whereas females consumed 250 mg cloves/kg diet had the lowest. Females fed 150 or 250 mg cloves/kg of diet showed the highest loin weight, whereas males receiving the same levels of cloves had the lowest. In contrast, males consuming 150 or 250 mg cloves/kg of diet had a higher hind part weight percentage, whereas females given the same clove doses had the lowest. Males fed 150 mg cinnamon/kg food as well as females fed 250 mg cinnamon/kg diet showed the largest proportion of hind part weight. In turn, males fed 250 mg cinnamon/kg diet and females fed 150 mg cinnamon/kg diet had the lowest high part proportions (Tab. 6).

Table 5. Means and standard deviations (in parentheses) of rabbit plasma constituents in response to cinnamon and clove supplements, sex and treatment x sex interaction

Item	Plasma constituents								
	total protein (g/L)	albumin (g/L)	globulin (g/L)	albumin/ globulin	glucose (mmol/L)	total cholesterol (mmol/L)	triglycerides (mmol/L)	AST (µkat/L)	ALT (µkat/L)
Treatment									
control	59.5^{b} (3.17)	32.2^{b} (2.09)	27.3^{c} (3.27)	1.18^{b} (0.18)	9.05^{a} (0.11)	2.33^{a} (0.04)	0.98^{a} (0.03)	1.19^{a} (0.10)	1.11^{a} (0.05)
cinnamon 150 mg/kg	63.0^{ab}(3.83)	32.9^{b} (1.37)	30.1^{b} (2.48)	1.09^{bc} (0.03)	5.88^{c} (0.28)	1.96^{bc} (0.09)	0.76^{c} (0.03)	0.99^{b} (0.05)	0.97^{c} (0.04)
cinnamon 250 mg/kg	71.8^{a} (5.25)	37.9^{a} (3.76)	33.9^{a} (2.64)	1.12^{bc} (0.11)	5.66^{c} (0.60)	1.83^{d} (0.02)	0.71^{d} (0.02)	0.95^{b} (0.7)	0.90^{d} (0.05)
cloves 150 mg/kg	61.7^{ab}(2.17)	34.4^{ab}(4.76)	27.3^{c} (4.22)	1.27^{a} (0.43)	7.83^{b} (0.35)	2.07^{b} (0.04)	0.82^{b} (0.02)	1.04^{b} (0.10)	1.00^{bc} (0.04)
cloves 250 mg/kg	62.0^{ab} (4.65)	34.5^{ab} (4.77)	32.4^{ab} (4.50)	1.08^{bc}(0.36)	7.71^{b} (0.52)	1.88^{cd}(0.06)	0.74^{c} (0.03)	1.03^{b} (0.15)	1.03^{b} (0.04)
Sex									
♂	64.1 (3.45)	31.6 (3.75)	32.5 (3.45	0.97 (.020)	8.21 (0.27)	2.01 (0.05)	0.80 (0.03)	1.01 (0.08)	0.99 (0.04)
♀	61.3 (3.12)	33.7 (3.48)	27.6 (3.27)	1.22 (.020)	7.88 (0.27)	2.07 (0.05)	0.83 (0.03)	1.09 (0.08)	1.03 (0.04)
P-value									
T	0.01	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.01
S	0.05	0.64	0.53	0.05	0.28	0.19	0.94	0.21	0.44
T x S	0.17	0.23	0.97	0.05	0.21	0.05	0.05	0.42	0.05

^{abcd}Means within each effect in the same column having different superscripts are significantly different at P≤0.05.
AST – aspartate aminotransferase; ALT – alanine aminotransferase; T – treatment; S – sex; T x S – effects of treatment x sex interaction.

Males and females given 250 mg cinnamon/kg of diet had the lowest plasma total cholesterol, triglyceride and ALT levels of any interaction groups. Females and males who were provided the control diet had higher plasma total cholesterol, triglyceride and ALT levels than the other interaction groups. In addition, females and males fed

Table 6. Significant treatment x sex interactions for rabbit growth, feed traits, carcass characteristics and plasma constituents as a result of cinnamon and clove supplementation

Item	Control		Clove				Cinnamon				*p*-value
			150 mg/kg		250 mg/kg		150 mg/kg		250 mg/kg		
	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	T x S
Growth and feed traits											
LBW_{72} (kg)	1.80^{e}	1.79^{e}	2.00^{a}	1.91^{b}	1.95^{ab}	2.00^{a}	2.01^{a}	1.96^{ab}	2.01^{a}	1.93^{b}	0.01
$LBWG_{30\text{-}72}$ (kg)	1.19^{d}	1.14^{e}	1.36^{ab}	1.27^{c}	1.38^{a}	1.30^{bc}	1.35^{ab}	1.30^{bc}	1.32^{abc}	1.30^{bc}	0.05
$FC_{30\text{-}72}$ (kg)	4.64^{cd}	4.24^{f}	4.77^{bc}	4.38^{ef}	4.74^{bcd}	4.39^{ef}	4.82^{b}	4.43^{e}	4.96^{a}	4.60^{d}	0.02
$FCR_{30\text{-}72}$	3.89^{a}	3.71^{ab}	3.59^{bc}	3.37^{c}	3.54^{bc}	3.38^{c}	3.54^{bc}	3.49^{bc}	3.59^{bc}	3.55^{bc}	0.01
Carcass traits											
Evisc. wt. (kg)	0.99^{d}	0.91^{g}	1.05^{c}	0.95^{ef}	1.00^{d}	0.94^{ef}	1.19^{b}	1.09^{c}	1.10^{c}	1.27^{a}	0.05
Dressing (%)	40.9^{fg}	40.1^{g}	46.4^{d}	48.2^{b}	47.9^{c}	49.5^{a}	41.1^{f}	45.1^{e}	45.1^{e}	47.8^{cd}	0.01
Meatiness (%)	38.2^{f}	36.2^{g}	41.9^{e}	41.6^{ef}	43.1^{d}	44.2^{c}	44.2^{c}	43.5^{cd}	44.4^{b}	44.7^{a}	0.01
Head (%)	6.97^{cd}	6.13^{e}	7.08^{c}	6.32^{de}	6.49^{d}	6.09^{e}	7.92^{a}	7.41^{b}	7.86^{a}	6.99^{c}	0.05
Liver (%)	4.14^{bc}	3.35^{f}	3.55^{e}	3.92^{c}	2.96^{g}	4.33^{a}	3.48^{ef}	4.20^{b}	3.28^{fg}	3.67^{d}	0.05
PF (%)	2.17^{ab}	2.23^{a}	1.20^{bc}	1.36^{b}	1.05^{cd}	1.41^{b}	1.09^{c}	1.03^{cd}	0.97^{d}	1.01^{cd}	0.02
SF (%)	2.77^{ab}	2.81^{a}	1.21^{c}	1.08^{d}	1.32^{bc}	1.08^{d}	1.19^{cd}	1.18^{cd}	1.04^{d}	1.85^{b}	0.02
FPW (%)	22.5^{b}	21.8^{d}	21.7^{de}	20.4^{e}	21.3^{de}	22.5^{b}	22.3^{c}	22.8^{a}	22.4^{c}	22.8^{a}	0.05
TCW (%)	17.5^{de}	17.4^{ef}	18.0^{d}	18.2^{c}	18.8^{bc}	17.0^{f}	19.5^{a}	19.0^{b}	19.4^{a}	18.2^{c}	0.05
LW (%)	30.0^{bc}	29.8^{d}	29.5^{e}	30.4^{a}	28.5^{f}	30.1^{bc}	30.0^{c}	29.9^{c}	30.4^{a}	30.2^{b}	0.05
HPW (%)	30.0^{e}	31.0^{b}	30.8^{c}	31.0^{b}	31.4^{a}	30.4^{d}	28.2^{g}	28.3^{g}	27.8^{h}	28.8^{f}	0.05
Plasma constituents											
TCHO (mmol/L)	2.21^{a}	2.32^{a}	1.91^{d}	2.00^{c}	1.82^{e}	1.83^{e}	2.05^{bc}	2.06^{bc}	1.90^{d}	1.85^{de}	0.05
TG (mmol/L)	0.84^{b}	0.98^{a}	0.74^{e}	0.77^{c}	0.70^{e}	0.71^{c}	0.83^{bc}	0.81^{bc}	0.75^{c}	0.72^{c}	0.05
ALT (µkat/L)	1.04^{b}	1.13^{a}	0.97^{bc}	0.96^{bc}	0.86^{c}	0.93^{bc}	1.02^{bc}	0.98^{bc}	1.01^{bc}	1.04^{b}	0.05
ALB□GLOB	1.05^{c}	1.30^{bc}	0.97^{cd}	0.93^{cd}	0.88^{d}	0.81^{d}	1.53^{a}	1.09^{c}	1.43^{b}	1.13^{c}	0.05

[abcdef]Means within treatment x sex interaction in the same row having different superscripts are significantly different at P≤0.05.

T x S – effects of treatment x sex interaction; LBW72 – live body weight at 72 days of age; $LBWG_{30\text{-}72}$ – live body weight gain from 30 to 72 days of age; $FC_{30\text{-}72}$ – feed consumption from 30 to 72 days of age; $FCR_{30\text{-}72}$ – feed conversion ratio from 30 to 72 days of age; Evisc. wt. – eviscerated weight; PF – perirenal fat, SF – scapular fat; FPW – fore part weight; TCW – thoracic cage weight; LW – loin weight; HPW – hind part weight; TCHO – total cholesterol; TG – triglycerides; ALT – alanine aminotransferase; ALB GLOB – albumin□globulin – immune index.

250 and 150 mg cinnamon/kg diet exhibited significantly higher immune indexes (Tab. 6).

The properties of phytogenic feed additives (cinnamon and cloves) may be responsible for the enhanced growth performance with stimulated and improved nutrient utilization by active materials (*eugenol* and *cinnamaldehyde*) found in cloves and cinnamon, respectively [El-Kholy *et al*. 2021], which are considered digestion stimulating factors, competing with pathogenic bacteria for colonization sites on the intestine surface [Lee *et al.* 2004, Al-Kassie and Jameel 2009], as well as stimulating digestive enzymes [Jayaprakasha *et al*. 2007].

Similarly, our findings support the results of previous studies indicating the effects of clove oil. Clove oil as a natural growth stimulant was proven to boost feed intake and body weight gain in rabbits at doses of 0.1, 0.2, and 0.3 ml/kg of body weight [Iqbal *et al*. 2021].

El-Kholy et al. [2012] found comparable results when using cinnamon as a phytobiotic in growing Black Baladi rabbits, concluding that the total benefits in increasing production performance were substantially attributed to cinnamon (*Cinnamomum zylenicum*) feed supplementation at 100 mg/kg diet.

These findings are in contrast to a recent study [El-Gindy *et al*. 2021], which reported non-significant variations in growth performance parameters (body weight, body gain, feed intake and feed conversion) in clove and rosemary oil treated groups against control rabbits at 400 mg/kg diet concentrations.

In turn, Suliman *et al*. [2021] showed inferior growth performance of broiler chicks given a high quantity of clove seeds (1 to 6%). This disparity might be attributed to the prior study's high amount of clove seed inclusion.

According to Toghyani *et al*. [2011] and Attia *et al*. [2019b] herbs may boost appetite and hence feed consumption. The stimulating effect of cinnamon or cloves on the gastrointestinal system, which promotes feed palatability and boosts appetite, may have contributed to the higher feed intake in all the treatment groups compared to the control.

That could also be attributed to increased total apparent retention of crude protein and organic matter observed in the cinnamon group [Chowdhury *et al*. 2018a], which is likely related to improving intestinal health through lowered numbers of pathogenic bacteria in the gut, as well as more efficient nutrient absorption capabilities and intestine barrier [Chowdhury *et al.* 2018b]. Additionally, the augmentation in feed intake appears to reflect the overall growth boosting effectiveness (increased consuming capacity due to better growth) via improved feed flavor and palatability [Windisch *et al.* 2008, Steiner 2009].

There was a significant difference in growth performance (LBW_{72}, $LBWG_{30-72}$, FC_{30-72}, and FCR_{30-72}) between cinnamon and clove treatments administered at 150 and 250 mg/kg of diet. This suggests that cinnamon was superior to cloves as a rabbit growth stimulant. This may be attributed to variations in the properties of each phytogenic feed addition. Furthermore, the cinnamon group showed greater

total tract apparent retention of crude protein and organic matter than the clove group [Chowdhury *et al*. 2018a].

These findings are consistent with those of Abedo *et al*. [2020] and El-Nomeary *et al.* [2020], who used cinnamon essential oils in growing NZW rabbits and found a significant impact ($p<0.05$) on carcass weight, without or with edible organs. The latter study showed that cinnamon essential oils increased carcass front part weight while lowering heart weight and overall edible offal weight. El-Kholy *et al*. [2012] also used cinnamon powder on growing Black Baladi rabbits and stated that the treatment resulted in a significant ($p\leq0.05$) increase in dressing percentage and weight of carcass internal organs.

These findings, on the other hand, contradict those of Abou-Kassem *et al*. [2021], who applied a herbal mix that did not include cinnamon or cloves, and Bassiony *et al.* [2015], who used diverse quantities of cinnamaldehyde essential oil bioactive compounds and observed that they did not significantly affect the carcass characteristics of NZW male rabbits.

These findings may be attributed to carcass weight mostly related to pre-slaughter weight, whereas carcass yield is primarily dependent to body composition, among many other factors phytogenic active substances have a significant influence on the lipid profiles in blood of growing rabbits at a decrease in perirenal fat and scapular fat deposition in this study. Augmented metabolism of carbohydrates and protein in the major organs would enhance the development of these organs. The influence of phytogenic feed additives, particularly cloves and cinnamon, on rabbit carcass parameters appears to be minor or limited.

Haematology analyses frequently provide crucial information concerning the body's reaction to a variety of situations that the animal confronts, as well as a signal to restore an animal's blood condition in order to meet its physiological, biochemical and metabolic demands [Musco *et al*. 2019, El-Deep *et al*. 2020], while also contributing to the diagnosis of nutritional, environmental or physical stress [Abdel-Azeem 2019]. This was consistent with a recent study [Iqbal et al. 2021], which detected that 0.2 ml/kg of body weight clove oil improved the blood profile. In the same context, clove oil, rosemary oil and combination essential oil treatments augmented RBC counts and haemoglobin concentrations ($p<0.01$) by roughly 9.62, 10.99and 8.78 % and 10.55, 11.64 and 11.64%, respectively, when compared to the control rabbits [El-Gindy *et al.* 2021]. As seen in Table 4, clove supplementation resulted in a significant decrease in MCV as compared to the control group; these findings suggest that the clove supplement may either directly or indirectly boost the formation of small-sized RBCs (reticulocytes).

In compared to the control group, rabbits fed cinnamon had the best neutrophil/lymphocyteratio, which might be attributable to an increase in lymphocytes and a decrease in neutrophils. The improvement in the neutrophil/lymphocyte ratio may be expressed in terms of stress intensity and used as a stress index [Abdel-Azeem 2019]. The ability of cinnamon and clove supplements to enhance immunity may account for

the higher lymphocyte percentage in the treated groups. This finding was supported by a low neutrophil/lymphocyte ratio, which indicated a stronger immune system. A decrease in the number of less mature neutrophil forms, also known as staff, stabs or bands, indicated that rabbits fed cinnamon or clove supplements were healthy.

The augmentation in the neutrophil percentage in the control group and the respective decrease in the treated groups, notably in the cinnamon supplement group, might suggest the severity of stress in the growing rabbits in the control group. Cinnamon and cloves also play a preventive effect in modulating the oxidative route of stress-induced harm. Additionally, the application of cinnamon and clove supplements in the diet may regulate stress and thus be a realistic dietary strategy in decreasing the risk of stress.

In this study the influence of sex on several rabbit growth, carcass traits and blood haematological indices was non-significant, mostly due to the rabbits' age of 72 days, which is far from the pubertal stage and sex hormone production [Abdel-Azeem *et al.* 2010].

The augmented plasma total protein of growing rabbits when supplemented with cinnamon and cloves indicated a high protein quality as well as the quantity and availability of dietary protein. The elevated plasma total protein, albumin and globulin levels were within the normal range in rabbits consuming different levels of supplementation, which revealed that a higher supplement level was both beneficial and safe.

Total protein and globulin of plasma are immune system components, together with albumin-based antibodies being major protein components of serum protein generated in the hepatic tissues, which serves as a humoral immune response and might assist the augmentation of immune organs. As a result, the current study's findings of plasma total protein and globulin levels suggested that cinnamon and clove supplements enhance the humoral immune response. Serum albumin regulates the distribution of extracellular fluid and acts as a transport mechanism for a number of chemicals, including bilirubin, fatty acids, hormones and vitamins [Attia *et al*. 2015].

These findings showed an effect on the plasma albumin/globulin ratio, which decreased from 1.18 in the control group to 1.08 in the 250 mg clove/kg of the diet and 150 mg cinnamon/kg of the diet-supplemented groups. A decline in the plasma albumin/globulin ratio may indicate improved immunity in rabbits [Abdel-Azeem *et al.* 2018].

Khan *et al*. [1990] revealed that an agent isolated from cinnamon called the "insulin-potentiating factor" that caused a threefold augment in glucose metabolism in epididymal fat cells of rats and ascribed it to the existence of a methyl hydroxy chalcone polymer. Cinnamon can also promote insulin receptor autophosphorylation and constrains protein tyrosine phosphatase-1, which deactivates insulin receptors in adipocytes [Jarvill-Taylor *et al*. 2001]. According to Qin *et al*. [2004], the cinnamon extract also inhibits the development of insulin resistance in the high fructose diet rat group. They ascribed this to the stimulation of insulin signs in skeletal muscle,

potentially via the nitric oxide route. Cinnamon definitely activates the insulin cascade system according to research findings reported by [Kannappan *et al*. 2006].

Cinnamon and cloves appear to lower blood glucose levels via stimulating the pancreas to synthesize and secrete insulin, interfering with dietary glucose absorption, as well as the insulin sparing effect of the component bioactive chemicals [Srinivasan 2005, Saravanan and Pari 2008]. It is also executed by limiting intestinal absorption and sodium-dependent reabsorption from renal tubules through active components (eugenol and cinnamaldehyde) that permeate enterocyte membranes and block the Na+-K+-ATPase, which provides the driving power for numerous transport activities [Kreydiyyeh *et al*. 2000]. Furthermore, the addition of cinnamon bark inhibited intestinal α-glucosidase and pancreatic α-amylase, resulting in a delay in carbohydrate digestion and thus lower glucose levels [Adisakwattana *et al*. 2011].

In the current study, the plasma total cholesterol and triglyceride biomarkers indicate significant differences in rabbits supported by cinnamon and clove supplementation when compared to the control group. The data point to a link between cinnamon and clove supplements and lipid profiles. Because plasma lipid profiles are generated in the liver, lower levels and better lipid profiles in plasma are considered indications of liver health. The lower plasma total cholesterol and triglycerides of the treated groups can be elucidated as a direct decline in blood glucose content. Lowering blood cholesterol and triglyceride levels might also be linked to pancreatic ß-cell regeneration by reducing 3-hydroxy-3-methylglutaryl coenzyme A reductase, a crucial enzyme in the production of cholesterol, and/or by lowering the NADPH necessary for the formation of fatty acids and cholesterol [Sharma *et al.* 2003, Vessal *et al.* 2003, Srinivasan *et al*. 2005]. Blood triglyceride levels in rabbits reduced by including cinnamon or clove supplements in their diets and with increased dietary levels of supplements, which may be attributed to constrained production of triglyceride compounds in the early action of glycerol-3-phosphate dehydrogenase, dihydroxyacetone phosphate, and NADH help make triglyceride-3-phosphate and decreased glycerol-3-phosphate activity in triglyceride biosynthesis [He *et al*. 2009]. The enhanced action of insulin in the cinnamon and clove supplement groups may be responsible for regulating total cholesterol and triglyceride metabolism, resulting in their lower total cholesterol and triglyceride levels. Numerous studies also showed that cinnamon extracts depressed blood total cholesterol and glucose levels [Mang *et al*. 2006, Blevins *et al.* 2007, Crawford 2009].

The aminotransferases, such as AST and ALT of blood, are enzymes indicating the quantity of intracellular hepatic enzymes that have seeped into the bloodstream. Moreover, they serve as a marker of hepatocyte damage [McGill 2016]. The reduction in aminotransferase levels in the cinnamon and clove supplement groups, as well as their levels being within the normal rabbit limits, indicated that no liver injury occurred. In this experiment the rabbits, particularly those that consumed a high level (250 mg) of cinnamon and clove supplementation, demonstrated a decrease in blood aminotransferase levels with an increase in the level of both cinnamon and clove

supplementation. The prior note showed that there were no clinical symptoms of toxicity or morbidity and that the high amount of supplements was healthy and safe.

These findings confirm the conclusion of Kreydiyyeh *et al*. [2000] that the active compounds in cinnamon and cloves can permeate the intestinal cell membrane and inhibit the Na+-K+-ATPase that provides the driving force for many transport processes.

The improvement in blood haematological and plasma biochemical indices throughout treatments, as well as the significant differences between the cinnamon and clove groups could be attributed to the presence of distinct types of active substances and variations in their concentration. The decrease in blood total cholesterol, triglycerides and liver enzymatic activities may be one of the most important causes for improving health. Such findings may explain the relationship between cinnamon and clove supplements and health efficiency, useful in increasing the rabbit productive efficiency.

It is possible that the improvement in rabbit growth, some carcass parameters, blood hematological and biochemical constituents when cinnamon and clove supplements were added to the diet was due to the distinct biological effects of the active components in each of them. Due to the various ratios of the main and active compounds in cloves and cinnamon, which result in diverse biological effects, this might explain the great inconsistency in the outcomes of research on phytogenic feed additives that has been or will be conducted.

It is concluded based on these findings that the cinnamon supplement administered at 250 mg/kg of diet in the fattening period may be an efficient approach to develop and boost growth and carcass traits of growing rabbits by augmenting the blood picture and biochemical constituents, which were within the normal range, and thus may be a major cause of abundant production.

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