

## **EFFECT OF DIETARY SUPPLEMENTATION OF CINNAMON AND CURCUMIN ON PERFORMANCE, CARCASS TRAITS, HUMORAL IMMUNE RESPONSES, AND BLOOD SERUM METABOLITES IN GROWING RABBITS**

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### **SUMMARY**

**A** total of seventy-two V-line rabbits of both sexes, 5 weeks old, with initial weights of  $639.4 \pm 25.97$  g were used for the study. Rabbits were randomly allocated to 6 treatment groups, each of which included 4 replicates of 3 rabbits. The experiment lasted for 6 weeks to be finished at 11 weeks of age and dietary treatments were as follows: 1) Control (basal diet); 2) basal diet+ 100 mg/kg antibiotic tylosin; 3) basal diet+ 0.5 g /kg turmeric (as a source of curcumin); 4) basal diet+ 1.0 g/kg turmeric; 5) basal diet+ 0.5 g/kg cinnamon; 6) basal diet+ 1.0 g /kg cinnamon. The results showed that there were significant ( $P \leq 0.05$ ) differences in body weight, weight gain, feed intake and feed conversion ratio among treatments and the control group. The highest body weight and weight gain values and the best feed conversion ratio were recorded in the groups given 1.0 g /kg diet turmeric or cinnamon. The highest feed intake values were observed in the control and Tyrosin fed groups, while the lowest feed intake values was recorded in cinnamon fed group. Tylosin, cinnamon and turmeric supplementation significantly ( $P \leq 0.05$ ) improved digestibility of DM, OM, CP, CF, EE and NFE and also, improved the nutritive values of nutrients as TDN and DCP in comparison with control. General significant ( $P \leq 0.05$ ) increase in RBCs, Hb and PCV % due to the different feed additives in comparison with control group. Serum lipid profile improved by phyto-genic feed additives compared with tylosin and control groups. Phyto-genic feed additives reduced Malondialdehyde ( $P \leq 0.05$ ), while, increased total antioxidant capacity concentrations and glutathione peroxidase activities. Immunostimulatory effects of phyto-genic feed additives were recorded. In conclusion, we state that cinnamon and turmeric could have beneficial effects on performance, digestibility, immunomodulatory and play an important role as an exogenous antioxidant.

**Keywords:** *Rabbits, cinnamon and turmeric, antibiotic, performance, immunity and blood lipid profile.*

### **INTRODUCTION**

Large numbers of feed additives are available for inclusion in animal and poultry diets to improve animal performance. Recently, many countries tend to prevent the application of antibiotics for their side effects. The ban on nutritive antibiotic use in the world and the augmented awareness of the consumers triggered a need for natural and safe feed additives to achieve better production results of farm animals therefore, nowadays growth promoters from herbal sources (phyto-genic extracts) are used very commonly (Zeweil *et al.*, 2016). The use of phyto-additives and their extracts in rabbit husbandry offers an acceptable way to improve welfare and health s (Szabóová *et al.* 2008)

Turmeric is a yellow powder driven from the rhizome of “*Curcuma longa*” with extensive use as spices particularly in south & south-east Asia and Middle East countries. Curcumin, the yellow pigment of turmeric, the main active component in turmeric (Jagetia and Aggarwal, 2007). Antioxidative properties have been reported for turmeric and curcumin in several studies (Reddy and Lokesh, 1994; Wei and Shibamoto, 2007). Also, it has been shown that turmeric and curcumin possess hypolipidemic effects (Dixit *et al.*, 1988; Babu and Srinivasan, 1997). Anti-inflammatory and immune system modulating effects of turmeric (Joe *et al.*, 1997; South *et al.*, 1997).

Cinnamaldehyde is the major component of cinnamon, creating about 65 percent of the extracted essential oil (Mountzouriset *al.*, 2009). Immune system stimulating effects has been reported for cinnamaldehyde (Nofrariaset *al.*, 2006). Also, considerable antibacterial (Tabak *et al.*, 1999; Chang *et al.*,

2001) and antifungal (Montes and Carvajal, 1998; Soliman and Badea, 2002) properties have been found for cinnamon essential oil. The aim of the present study is to determine the effects of cinnamon and turmeric powder as phytogetic feed additives instead of antibiotic on growth performance, digestibility, blood hematology, immune response, blood serum lipid profiles and antioxidant status in growing rabbits through summer season

## MATERIALS AND METHODS

A total of seventy-two V-line rabbits of both sexes, 5 weeks old, with initial weights of  $639.4 \pm 25.97$ g were used for the study. Rabbits were randomly allocated to 6 treatment groups, each of which included 4 replicates of 3 rabbits. The experiment lasted for 6 weeks to be finished at 11 weeks of age and dietary treatments were as follows: 1) Control (basal diet); 2) basal diet+tylosinantibiotic; 3) basal diet+ 0.5 g /kg cinnamon; 4) basal diet + 1.0 g/kg cinnamon; 5) basal diet+ 0.5 g/kg turmeric (as a source of curcumin); 6) basal diet+ 1.0 g /kg turmeric. Pellets of the experimental diets were made as follow, pelleting was initiated by molasses addition as binding material and then all diet ingredients were pressed at 70C°, after that pellets were cooled. Rabbits were housed in wire floor batteries of (40 cm high x 30 cm width x 50 cm length) and were offered diets for duration of the feeding trial until reaching 11 weeks of age through summer season from mid-July to September. All rabbits were kept under the same managerial, hygienic and environmental conditions. The experimental diets were offered to rabbits *ad libitum*.

The formula of basal experimental diet is presented in Table (1) that formulated to cover the requirements of rabbits according to NRC (1977).

**Table (1). Composition and chemical analyses of the basal experimental diet.**

Ingredients	%
Yellow corn	19.0
Wheat bran	11.0
Barley	17.2
Alfalfa hay	33.0
Soybean meal (44%)	15.0
Molasses	3.0
Di-calcium phosphate	1.0
L-lysine	0.1
DI-Methionine	0.1
Premix	0.3
Salt	0.3
Total	100
<u>Chemical analyses</u>	
Dry matter (DM), %	91.36
Crude protein%	17.24
Ether extract%	3.26
Crude fiber%	12.58
Nitrogen free extract%	50.47
Ash%	7.57
Organic matter (OM), %	92.42
DE (kcal/kg DM) <sup>2</sup>	2749.78

<sup>1</sup>Vit+Min mixture provides per kilogram contains: Vit A 6000 IU; Vit D<sub>3</sub> 450 IU; Vit E 40 mg; Vit K<sub>3</sub> 1 mg; Vit B<sub>1</sub> 1 mg; Vit B<sub>2</sub> 3 mg; Vit B<sub>3</sub> 180 mg; Vit B<sub>6</sub> 39 mg; Vit B<sub>12</sub> 2.5 mg; Pantothenic acid 10 mg; biotin 10 mg; folic acid 2.5 mg; choline chloride 1200 mg; Manganese 15 mg; Zinc 35 mg; Iron 38 mg; Copper 5 mg; Selenium 0.1 mg; Iodine 0.2 mg; Selenium 0.05 mg.

<sup>2</sup>Analyzed values according to AOAC (1995).

DE calculated according to Fekete and Gippert (1986) using the following equation: DE (kcal/ kg DM) = 4253 - 32.6 (CF %) -144.4 (total ash).

Rabbits were housed in well ventilated block building. Fresh air circulated in the house using exhaust fans. The rabbits were kept within a cycle of 16 h light and 8 h dark. Antibiotic tyrosin was obtained from Chemical Industries Development (CID) El-Tibia-Pyramids-Giza-A.R.E-G.C.R19717- Giza, Egypt). Cinnamon and turmeric were obtained from Imtenan Health Shop, 20 Mohamed Bahaa El-Din El-Ghatory, Semouha, Alexandria, Egypt). Individual body weight and feed consumption were recorded weekly. Body weight gain and feed conversion ratio were calculated. The incidence of dangerous diseases was largely avoided and rabbits have never been treated with any kind of systematic vaccination or medication. Mortality rate was recorded as a number of dead animals in each group during the whole experimental period and percentage calculated.

Three rabbits per treatment were housed individually in the digestibility cage for 7 days to collect feces and urine. Shaded hair or non-fecal materials were eliminated. Feces and urine were collected quantitatively daily morning, and weight fresh and stored at 4°C in a refrigerator. The seven days combined collection were sampled and kept for analysis. Fecal samples were dried at 60 °C for 72 h. Feeds and fecal samples were 1 mm screen grinded by a wiley mill grinder and the samples (20 g/sample/treatment/rabbit) were analyzed. The samples of feed and feces were analyzed for crude protein (CP), crude fiber (CF), ether extract (EE) and ash were analyzed according to AOAC (2005). Values of the total digestible nutrients (TDN; DCP) were calculated according to the classic formula of Cheeke *et al.* (1987) on a dry matter basis from feed and fecal samples content of dry matter (DM).

At the end of the feeding trial, 3 rabbits were selected from each treatment group randomly, starved of food but not water for 12 hours and slaughtered for carcass analysis. Before slaughtering, 6 ml of blood sample was taken from the ear vein with a sterile syringe. 3 ml of the blood was put into a bijon bottle containing ethylene diaminetetracetic acid (EDTA) as an anticoagulant for hematological assay. The remaining 3ml of the blood sample was put into a sterile vacutainer tube without an anticoagulant for serum biochemical analysis. The hematological assay was carried out to determine erythrocyte indices such as packed cell volume (PCV), and hemoglobin (Hb) values. Red blood cell (RBC) counts were counted on an AO Bright line hemocytometer using a light microscope at 400X magnification after diluting blood samples 200 times with a physiological saline (0.9% NaCl solution) before counting (Natt and Herrick, 1952). White blood cell (WBC) were counted on an AO Bright line hemocytometer using a light microscope with a little of Leishman's stain before counting (Hepler, 1966). Total lipids, triglycerides, total cholesterol, low density lipoprotein (LDL) , high density lipoprotein (HDL), total antioxidant capacity (TAC), lipid peroxidase (MAD) and glutathione peroxidase (GP) concentrations in serum were estimated using commercial kits (Bio Merieux, France) according to the procedure outlined by the manufacturer. Serum immunoglobulin IgG was determined using ELISA technique. Three rabbits of each treatment were immunized with 0.1 ml of a 2.5% Sheep Red Blood Cells (SRBCs) via the marginal ear vein at 15 days after starting the dietary treatment supplementation, to measure antibody titer against sheep red blood cells. The dosage of SRBC for inoculation was pre-determined by a separate trial. Antiserum to SRBCs was collected 14 days post challenge according to Wegmann and Smithies, (1966). The agglutination titer was expressed as the  $\log^2$  of the reciprocal of the highest serum dilution giving complete agglutination (Nelson *et al.*, 1995). The results were expressed as the mean  $\pm$  SE. All data were analyzed using one way analysis of variance (ANOVA) using SPSS 11.0 statistical software (SPSS, Inc., Chicago, Il, 2001). Significant differences between means were detected using new Duncan multiple range test (Duncan, 1955). The differences among mortality rate were tested by chi-square.

## **RESULTS AND DISCUSSION**

There were significant ( $P \leq 0.05$ ) differences in body weight, weight gain, feed intake and feed conversion ratio among treatments and the control group (Table 2). The highest body weight and the best feed conversion ratio were recorded in the groups given 1.0 g /kg turmeric or cinnamon. Besides, the highest weight gain value was found in the group given 1.0 g cinnamon/ kg diet. Furthermore, the lowest final body weight and weight gain and the poorest feed conversion ratio were found in the control group. Moreover, the highest feed intake values were observed in the control and tyrosin groups, while the lowest feed intake values was recorded in cinnamon fed group. In fact, mortality percent was not different among the groups that may be due to good hygienic condition of the farm and good sanitary status of the digestive system.

The improvement in performance of rabbits with phytogetic additives may be also due to providing some compounds that enhance digestion and absorption of some nutrients in the diets, that may be attributed to the bioactive components (curcuminoids, curcumin and cinnamaldehyde and eugenol) found in turmeric and cinnamon that cause greater efficiency in the utilization of feed, resulting in enhanced growth.

The most efficient feed conversion ratio in rabbits fed diets supplemented with antibiotic, turmeric and cinnamon powder reveals that the impact of growth promoter substances may be related to a more efficient use of nutrients. Cinnamon and turmeric improved the performance that may be due to reduced levels of peroxidation (blood serum MDA), and or due to the active components that enhance digestion and absorption of dietary nutrients. The results presented by Hussein (2012) reported that *curcuminoids* and *curcumin* of turmeric increased utilization of feed, resulting in enhanced growth. Turmeric extract demonstrated high potential to inhibit some pathogenic bacteria of chicken (Ong-ardet *et al.*, 2010). Cinnamon has strong antibacterial properties, anticandidal, antiulcer, analgesic, antioxidant and hypocholesterolaemic activities (Mastura *et al.*, 1999; Shihabudeen *et al.*, 2011). The essential oil from *Cinnamomum zeylanicum* bark is rich in trans-cinnamaldehyde with antimicrobial effects against animal pathogens (Mastura *et al.*, 1999). Thus, alike antibiotics, turmeric and cinnamon may control and limit the growth and colonization of numerous pathogenic and non-pathogenic species of bacteria in chickens' gut resulting in balanced gut microbial ecosystems that leads to better feed utilization reflected by improved feed conversion ratio. Corresponding to our results on feed efficiency, Durrani *et al.* (2006) also reported that chickens receiving diets supplemented with 5 g/kg turmeric powder had better feed conversion ratio than 2.5 and 10 g/kg supplementation level. Our results were in agreement with those of Wuthi-Udomler *et al.* (2000) and Samarasinghe *et al.* (2003) who found that birds fed turmeric powder had lower feed intake and feed conversion ratio in comparison with control. However, the present results were in disagreement with those of Peiretti *et al.* (2011) who found that the growth performance parameters of growing rabbits were not affected by dietary curcuma supplementation (3 g/kg diet). Also, Basavaraj *et al.* (2010) showed addition of turmeric 150, 300 mg to rabbit's diet did not affect the body weight gain and feed intake. Naderi *et al.* (2014) reported that feed intake of broilers was not affected by any of the dietary additives (avilamycin, turmeric powder 2.5g/kg, or cinnamon powder 7.5g/kg diet) during different periods of the experiment. Also, Song-oh *et al.* (2013) found insignificant effect on feed intake due to inclusion of cinnamon in the diet in comparison with control. El-Kholi *et al.* (2012) reported that rabbits fed the cinnamon supplemented diet (500; 1000 and 1500 g/Ton diet) had significant increase at 60 days in final body weight; daily weight gain and feed intake and feed efficiency values compared to the control group.

In general, antibiotic tylosin, cinnamon and turmeric supplementation significantly ( $P \leq 0.05$ ) improved digestibility of DM, OM, CP, CF, EE and NFE in comparison with control (Table 3). Digestion coefficients of dry matter, organic matter, crude protein and ether extract were the best in the groups had 1.0 g/kg turmeric, 0.5 and 1.0 g/kg cinnamon in comparison with control, tylosin and 0.5 /kg turmeric treatments. The results showed also that tylosin and 0.5 g/kg turmeric significantly ( $P \leq 0.05$ ) exceed the control group in the aforementioned traits. There is evidence to suggest that herbs, spices, and various plant extracts have appetite- and digestion-stimulating properties and antimicrobial effects (Kamel, 2001). Plant extracts contain different molecules that have intrinsic bioactivities on animal physiology and metabolism. The mechanisms by which these products influence the gut microflora and growth performance of poultry are not known. The plant extract clearly demonstrate antibacterial properties, although the mechanistic processes are poorly understood (Dorman and Deans, 2000). Al-Sultan and Gameel (2004) reported that curcumin can accelerate the emulsification of fat by stimulating the production of bile so that the digestion of fat will be more optimal. Astawa *et al.* (2016) showed that the digestibility coefficient of organic matter and crude protein was the best in turmeric extract at 0.04 ml/kg body weight than the groups received 0.02 ml of turmeric extract /kg body weight compared to the control group. The results obtained were significantly different because turmeric extract may increase the production and secretion of bile into the small intestine so that digestion of fats, protein, and carbohydrates increased.

Total digestible nutrients (TDN) and digestible crude protein (DCP) were significantly ( $P \leq 0.05$ ) improved by the different feed additives in comparison with the control group. The best value of TDN was record in the group supplemented with 1.0 g/kg cinnamon. However, the best value of DCP was record in the groups had 0.5 and 1.0g /kg cinnamon, 0.5 and 1.0 g/kg turmeric (Table 3).

**Table (2). Effect of tylosin, turmeric and cinnamon on growing V-line rabbits performance.**

Characteristics	Control	Tylosin 100 mg/kg	Turmeric (g/kg)		Cinnamon (g/kg)	
			0.5	1.0	0.5	1.0
Initial body weight, g	630.20±29.51	633.42±27.90	636.81±27.32	645.73±15.43	638.92±29.3	651.24±26.39
Final body weight, g	1887.93 <sup>d</sup> ±54.53	1969.70 <sup>c</sup> ±44.81	1999.90 <sup>b</sup> ±42.1	2135.21 <sup>a</sup> ±32.7	1993.92 <sup>b</sup> ±52.20	2154.61 <sup>a</sup> ±58.20
Total weight gain, g	1257.62 <sup>e</sup> ±21.42	1336.32 <sup>d</sup> ±22.74	1363.10 <sup>c</sup> ±19.7	1489.51 <sup>b</sup> ±20.70	1355.01 <sup>c</sup> ±22.4	1503.40 <sup>a</sup> ±24.73
Total feed intake, g	3559.50 <sup>a</sup> ±79.21	3521.71 <sup>a</sup> ±101.22	3474.63 <sup>b</sup> ±98.10	3447.8 <sup>c</sup> ±98.21	3381.44 <sup>d</sup> ±96.02	3388.01 <sup>d</sup> ±97.13
Feed conversion ratio	2.83 <sup>a</sup> ±0.03	2.63 <sup>bc</sup> ±0.10	2.54 <sup>c</sup> ±0.08	2.31 <sup>d</sup> ±0.09	2.49 <sup>c</sup> ±0.02	2.25 <sup>d</sup> ±0.04
No of dead rabbits (%)	2/12 (16.7%)	0/12 (0%)	1/12 (8.33%)	1/12(8.33%)	0/12 (0%)	1/12(8.33%)

*Different letters (a-d) within a row denote significant differences between treatments (P ≤ 0.05).*

**Table (3). Effect of tylosin, turmeric and cinnamon on growing V-line rabbits digestibility coefficients.**

Characteristics	Control	Tylosin 100 mg/kg	Turmeric (g/kg)		Cinnamon (g/kg)	
			0.5	1.0	0.5	1.0
<i>Digestibility of</i>						
Dry matter, %	66.07 <sup>c</sup> ±1.09	71.66 <sup>b</sup> ±1.18	69.13 <sup>b</sup> ±1.23	73.05 <sup>a</sup> ±1.15	73.89 <sup>a</sup> ±1.12	74.27 <sup>a</sup> ±1.06
Organic matter, %	89.10 <sup>c</sup> ±1.67	91.52 <sup>a</sup> ±1.52	90.50 <sup>b</sup> ±1.54	92.75 <sup>a</sup> ±1.56	92.05 <sup>a</sup> ±1.59	92.90 <sup>a</sup> ±1.32
Crude protein, %	62.17 <sup>c</sup> ±1.16	65.94 <sup>b</sup> ±1.15	64.99 <sup>b</sup> ±1.18	70.97 <sup>a</sup> ±1.20	70.04 <sup>a</sup> ±1.19	72.54 <sup>a</sup> ±1.23
Crude fiber, %	42.84 <sup>c</sup> ±1.09	48.00 <sup>b</sup> ±1.04	45.42 <sup>b</sup> ±1.02	52.52 <sup>a</sup> ±1.13	53.03 <sup>a</sup> ±1.10	53.15 <sup>a</sup> ±1.07
Ether extract, %	46.19 <sup>c</sup> ±2.09	51.61 <sup>a</sup> ±2.20	48.83 <sup>b</sup> ±2.12	51.14 <sup>a</sup> ±2.21	50.56 <sup>a</sup> ±2.19	52.48 <sup>a</sup> ±2.23
Nitrogen free extract,%	55.60 <sup>b</sup> ±1.89	59.62 <sup>a</sup> ±1.73	58.40 <sup>a</sup> ±1.85	59.75 <sup>a</sup> ±1.46	59.15 <sup>a</sup> ±1.52	59.80 <sup>a</sup> ±1.48
<i>Nutritive values</i>						
TDN%	55.71 <sup>c</sup> ±0.23	62.80 <sup>b</sup> ±0.21	59.24 <sup>b</sup> ±0.24	60.08 <sup>b</sup> ±0.28	61.39 <sup>b</sup> ±0.30	64.38 <sup>a</sup> ±0.19
DCP	10.84 <sup>c</sup> ±0.07	11.49 <sup>b</sup> ±0.06	11.37 <sup>b</sup> ±0.12	12.41 <sup>a</sup> ±0.08	12.20 <sup>a</sup> ±0.13	12.67 <sup>a</sup> ±0.17

*Different letters (a-c) within a row denote significant differences between treatments (P ≤ 0.05).*

Results for hematological parameters of the rabbits in Table (4) showed that all hematological parameters at control group were significantly decreased through the Egyptian summer season; however, a general significant ( $P \leq 0.05$ ) increase in RBCs, WBCs, Hb and PCV % due to the different feed additives in comparison with control group was observed. One of the mechanisms to dissipate heat from the body is by panting (thermal panting) increased respiratory rate with a decreased tidal volume (Ludders, 2004). Study by Comito *et al.* (2007) reported that thermal panting could decrease hemoglobin synthesis. Curcumin in turmeric can accelerate the emulsification of fat by stimulating the production of bile (Al-Sultan and Gameel, 2004) so that the digestion of fat will be more optimal. Optimized fat digestion will indirectly increase the provision of substrates for  $\beta$ -oxidation or fat metabolism which eventually enhances the production of succinyl-CoA through Krebs metabolic cycle (Cunningham and Klein, 2007). Considering succinyl-CoA is one of the materials needed for hemoglobin (heme in particular) synthesis (Bunn and Forget, 1986), enhanced succinyl-CoA production was therefore most likely to be followed by the increase of hemoglobin synthesis. The principal component of erythrocytes is hemoglobin, which makes up about one-third of the erythrocytes content (Reece, 2009). Thus, enhanced hemoglobin concentration due to turmeric extract should be followed by the enhanced erythrocytes concentration. Hematocrit measures the percentage of the volume of whole blood that is made up of red blood cells (Reece, 2009). Hematocrit is strongly affected by red blood cells concentration in the blood. Thus, alongside with the concentration of erythrocytes, turmeric having significant effect ( $P \leq 0.05$ ) on hematocrit level (Table 4) could be accepted. In disagreement with the present results, Baghban *et al.* (2016) showed that turmeric and cinnamon either alone or together did not change levels of hematocrit. Similarly, Hosseini-Vashanet *et al.* (2012) reported no changes in hemoglobin and hematocrit values of broilers fed up to 8 g/kg turmeric powder.

The normal PCV indicates the absence of normocytic anemia which is reportedly characterized by normal MCV and MCH and only detected by a decreased number of RBCs or PCV (Coles, 1986). The result is corroborated by the normal RBCs which further elucidated the absence of hemolytic anemia and depression of erythropoiesis. The normal hemoglobin concentration for all the experimental rabbits is probably an indication that these feed additives supported hemoglobin synthesis, (Sirosis, 1995) is among other factors, primarily affected by protein intake or may be due to iron deficiency and its improper utilization for the formation of hemoglobin (Ogbuwuet *et al.*, 2013). Njidda *et al.* (2006) reported that normal range of values for Hb indicated that the vital physiological relationship of hemoglobin with oxygen in the transport of gases (oxygen and carbon dioxide) to or from the tissues of the body has been maintained and was normal. Emadi *et al.* (2007) demonstrated that turmeric supplementation into the basal diets of broilers did not affect haematocrit value at 42 days of age.

Determined antibody titers against SRBCs are shown in Table (4) as affected by different feed additives. The different phytogetic feed additives significantly ( $P \leq 0.05$ ) increased antibody titers against SRBCs compared with control and tylosin fed groups after 14 days of vaccination. This may be attributed to that, the use of different phytogetic feed additives eliminate immune response against some diseases. Serum IgG was enhanced ( $P \leq 0.05$ ) in rabbits fed diets containing phytogetic additives and tylosin in comparison with control. However, the effect of phytogetic additives was more pronounced than tylosin. Cinnamon and turmeric addition may improve the immune system due to the increase in the immunoglobulin concentrations (IgG) of rabbits versus the control and tylosin containing diet. It is shown that cinnamon and turmeric were significantly an immunomodulatory. It was observed by Kumari *et al.* (2007) that supplementation of broilers diets with turmeric increased serum Zn concentration which can be related to increased antioxidant defense. Also Churchill *et al.* (2000) reported that an increase in CD4 T-lymphocytes as well as B-lymphocytes in mice consuming 1 gram curcumin per kilogram of the diet. Immunostimulatory effects of turmeric have been demonstrated by Chandrasekaran *et al.* (2013). The study of Song-Oh *et al.* (2013) reported that the IgG, IgA and IgM levels of the cinnamon powder fed groups were significantly higher than control group. Specifically, in 5 % cinnamon powder fed group which represented the greatest increase when compared with control. Also, Sadeghi *et al.* (2012) reported that cinnamon infusion improved antibody titers against Newcastle disease virus (NDV) in comparison to control group.

Results illustrated in Table (5) showed the effect of different treatments on blood serum lipid profile. It was observed that serum total lipids, triglycerides, total cholesterol and low density lipoprotein (LDL) significantly ( $P \leq 0.05$ ) decreased with different levels of cinnamon and turmeric in comparison with the group received tylosin in their diet and control group. On the other hand, high density lipoprotein (HDL) concentration was significantly ( $P \leq 0.05$ ) increased in the groups fed cinnamon and turmeric as compared with tylosin and control fed groups.

**Table (4). Effect of tylosin, turmeric and cinnamon on growing V-line rabbits blood hematology, antibody titers and serum IgG.**

Characteristics	Control	Tylosin 100 mg/kg	Turmeric (g/kg)		Cinnamon (g/kg)	
			0.5	1.0	0.5	1.0
<i>Hematology</i>						
RBC ( $\times 10^6/\text{mm}^3$ )	4.72 <sup>b</sup> $\pm 0.38$	5.79 <sup>a</sup> $\pm 0.14$	5.83 <sup>a</sup> $\pm 0.23$	5.98 <sup>a</sup> $\pm 0.47$	5.73 <sup>a</sup> $\pm 0.16$	5.84 <sup>a</sup> $\pm 0.33$
HB (g/100ml)	9.00 <sup>b</sup> $\pm 0.58$	11.16 <sup>a</sup> $\pm 0.17$	11.00 <sup>a</sup> $\pm 0.40$	11.37 <sup>a</sup> $\pm 0.97$	11.42 <sup>a</sup> $\pm 0.22$	11.39 <sup>a</sup> $\pm 0.49$
PCV (%)	31.43 <sup>b</sup> $\pm 1.23$	34.03 <sup>a</sup> $\pm 0.8$	34.40 <sup>a</sup> $\pm 1.15$	34.33 <sup>a</sup> $\pm 2.39$	34.30 <sup>a</sup> $\pm 0.49$	34.93 <sup>a</sup> $\pm 1.10$
WBC ( $\times 10^3/\text{mm}^3$ )	3.42 <sup>b</sup> $\pm 1.09$	3.53 <sup>b</sup> $\pm 0.46$	5.46 <sup>a</sup> $\pm 0.73$	5.54 <sup>a</sup> $\pm 0.27$	5.48 <sup>a</sup> $\pm 0.28$	5.63 <sup>a</sup> $\pm 0.72$
<i>Antibody titers and serum IgG</i>						
SRBCs at 14 day	0.694 <sup>c</sup> $\pm 0.01$	0.724 <sup>c</sup> $\pm 0.03$	0.908 <sup>b</sup> $\pm 0.02$	0.953 <sup>a</sup> $\pm 0.04$	0.963 <sup>a</sup> $\pm 0.02$	0.968 <sup>a</sup> $\pm 0.03$
Serum IgG (mg/dl)	209.6 <sup>c</sup> $\pm 5.781$	246.7 <sup>bc</sup> $\pm 27.28$	285.0 <sup>b</sup> $\pm 10.41$	298.3 <sup>ab</sup> $\pm 12.02$	340.0 <sup>a</sup> $\pm 17.32$	341.3 <sup>a</sup> $\pm 18.89$

*Different letters (a-c) within a row denote significant differences between treatments ( $P \leq 0.05$ ).*

**Table (5). Effect of tylosin, turmeric and cinnamon on growing V-line rabbits blood serum lipid profile and antioxidant status.**

Characteristics	Control	Tylosin 100 mg/kg	Turmeric (g/kg)		Cinnamon (g/kg)	
			0.5	1.0	0.5	1.0
<i>Serum lipid profile</i>						
Total lipids (mg/dl)	247.00 <sup>a</sup> $\pm 10.11$	229.00 <sup>b</sup> $\pm 4.41$	212.00 <sup>c</sup> $\pm 7.62$	204.00 <sup>c</sup> $\pm 6.43$	205.00 <sup>c</sup> $\pm 6.84$	201.00 <sup>c</sup> $\pm 6.56$
Triglycerides (mg/dl)	55.66 <sup>a</sup> $\pm 1.15$	54.02 <sup>a</sup> $\pm 2.51$	53.00 <sup>b</sup> $\pm 1.00$	52.33 <sup>b</sup> $\pm 0.33$	52.00 <sup>b</sup> $\pm 0.58$	52.00 <sup>b</sup> $\pm 1.20$
Cholesterol (mg/dl)	93.66 <sup>a</sup> $\pm 0.66$	94.12 <sup>a</sup> $\pm 4.84$	72.13 <sup>b</sup> $\pm 1.15$	71.00 <sup>b</sup> $\pm 4.70$	73.15 <sup>b</sup> $\pm 4.81$	76.00 <sup>b</sup> $\pm 2.00$
HDL (mg/dl)	33.66 <sup>b</sup> $\pm 0.88$	34.00 <sup>b</sup> $\pm 0.58$	45.33 <sup>a</sup> $\pm 1.20$	44.73 <sup>a</sup> $\pm 0.33$	42.23 <sup>a</sup> $\pm 1.20$	43.20 <sup>a</sup> $\pm 0.33$
LDL (mg/dl)	20.31 <sup>a</sup> $\pm 7.35$	20.87 <sup>a</sup> $\pm 2.33$	17.67 <sup>b</sup> $\pm 7.62$	18.98 <sup>b</sup> $\pm 0.58$	15.93 <sup>b</sup> $\pm 2.67$	14.16 <sup>b</sup> $\pm 1.73$
<i>Antioxidant status</i>						
TAC (mM/L)	1.60 <sup>c</sup> $\pm 1.23$	1.72 <sup>b</sup> $\pm 1.57$	2.21 <sup>a</sup> $\pm 1.85$	2.24 <sup>a</sup> $\pm 2.56$	2.24 <sup>a</sup> $\pm 3.25$	2.27 <sup>a</sup> $\pm 2.28$
MDA (nmol/ml)	20.11 <sup>a</sup> $\pm 3.25$	19.19 <sup>a</sup> $\pm 6.18$	17.34 <sup>b</sup> $\pm 3.04$	17.11 <sup>b</sup> $\pm 5.47$	16.84 <sup>b</sup> $\pm 6.77$	16.20 <sup>b</sup> $\pm 8.22$
GSP (nmol/ml)	10.51 <sup>c</sup> $\pm 2.58$	11.92 <sup>b</sup> $\pm 3.57$	12.37 <sup>a</sup> $\pm 4.12$	12.44 <sup>a</sup> $\pm 5.42$	12.50 <sup>a</sup> $\pm 4.36$	12.91 <sup>a</sup> $\pm 1.95$

*Different letters (a-c) within a row denote significant differences between treatments ( $P \leq 0.05$ ).*

The results showed insignificant differences between control and tylosin groups concerning triglycerides, total cholesterol, HDL and LDL. These results may be due to the cinnamon inhibition mechanism of 3-hydroxy-3-methylglutaryl-coenzyme A reductase (HMG-CoA reductase) activity. Two key enzymes involved in regulating cholesterol metabolism are HMG-CoA reductase, the rate-limiting enzyme in the cholesterol biosynthetic pathway and Acyl-CoA: cholesterolacyltransferase (ACAT), the cholesterol-esterifying enzyme in tissue. The inhibition of HMG-CoA reductase decreases cholesterol synthesis and its inhibitors are very effective in lowering plasma cholesterol in most animal species, including humans (Alberts 1988). Cinnamic acid (0.02%, w/w) and its synthetic derivatives (HPP304, HPP305) significantly inhibit hepatic HMG-CoA reductase activity and decrease serum total cholesterol level (Lee *et al.* 2001 & 2007). The present results were in agreement with those of Ciftci *et al.* (2010) reported that total cholesterol of the serum ( $P \leq 0.01$ ), thigh and breast meat ( $P \leq 0.05$ ) were found to be lower in both cinnamon groups (500 and 1000 ppm of cinnamon oil). On the other hand, Lee *et al.* (2003) failed to show any hypocholesterolemic effects of the active items as cinnamaldehyde. Wientarsih *et al.* (2002) reported that *Curcuma longa* supplementation to the rabbit diets significantly decreased LDL, total cholesterol and triglycerides concentrations in plasma. Where, inclusion of *Curcuma longa* in the rabbit diets led to an increase in the 3-hydroxy-3-methylglutaryl coenzyme reductase inhibitor activity (Wientarsih *et al.*, 2002); thereby, the reduction of 3-hydroxy-3-methylglutaryl coenzyme reductase resulted in a decrease in total cholesterol biosynthesis in rat cells (Amin *et al.*, 1993). The obtained results were in agreement with Alagawany *et al.* (2016) who found that triglycerides, total cholesterol and low density lipoprotein concentrations were linearly and quadratically decreased with increasing the dietary proportion of turmeric. Also, Hussein (2013) clearly found that triglycerides and total cholesterol were significantly decreased with increasing turmeric levels to 7 g/kg diet. The reduction of lipids profile (triglycerides, total cholesterol and low density lipoprotein concentrations) may be due to curcumin that enhances bile production and hence lipid digestion (Al-Sultan and Gameel, 2004). Asai and Miyazawa (2001) indicated that liver triacylglycerol and cholesterol concentrations were significantly lower in rats fed curcumin than in control animals. Plasma triacylglycerol in the very low-density lipoproteins fraction were also lower in curcumin fed rats. Hepatic acyl-CoA oxidase activity of the curcumin group was significantly higher than that of the control. The obtained results in the present study contrast with the results reported by Emadi *et al.* (2007) who demonstrated that turmeric supplementation into the basal diets of broilers significantly increased total cholesterol and HDL-cholesterol and decreased LDL-cholesterol, but did not affect total triglycerides.

Table 5 presents the results on the effects of different supplementations on serum total antioxidant capacity, malondialdehyde and glutathione peroxidase concentrations of growing rabbits.

Rabbits exposed to high temperature conditions during summer season resulted in significant decrease ( $P \leq 0.05$ ) in serum total antioxidant capacity (TAC) and glutathione peroxidase (GP) and significant increase in malondialdehyde (MDA), however, feeding rabbits phyto-genic cinnamon and turmeric supplemented diet improved the TAC and antioxidant enzyme (GP) and reduced the MDA concentration in comparison with the control group. Antibiotic tylosin also significantly ( $P \leq 0.05$ ) improved TAC and GP in comparison with control, however, the phyto-genic feed additives was more effective than antibiotic. Our results are also supported by Benzie and Wachtel-Galor (2011) who reported that turmeric extract (1.66 mg/kg of body weight) given to rabbits fed a high-fat diet, oxidation of erythrocyte membranes was found to be significantly lower than that in membranes of control animals. Superoxide dismutase (SOD) "metalloprotein enzyme" is the first enzyme contributed in the antioxidant defense system. Glutathione Peroxidase (GSH-Px) "seleno enzyme" catalyses the reaction of hydro peroxides with reduced glutathione to form glutathione disulphide. Consequently, elevated levels of these enzymes may improve the steady state of antioxidant system of rabbits. Quiles *et al.* (2002) reported that supplementation with *Curcuma longa* reduces oxidative stress and attenuates the development of fatty streaks in rabbits fed a high cholesterol diet.

Supplementation of basal diet with cinnamon and turmeric could equally improve blood serum glutathione peroxidase in rabbits and were more effective than tylosin, as compared with control. Ashour *et al.* (2014) reported that antioxidant enzymes including GSH-Px and SOD are synthesized and regulated endogenously. The SOD plays an important role in protecting cells from damage caused by reactive oxygen species (ROS), but this process requires dietary supply of the appropriate nutrients (Ashour *et al.*, 2014). Such antioxidant effects would be expected to improve the health of rabbits. From these results, it can be stated that supplementation with phyto-genic additives as cinnamon or turmeric could be applied in the future to improve the nutritional quality of rabbit meat. It seems that cinnamon and turmeric supplementation to basal control diet was effective in enhancing the antioxidant ability of rabbits. These effects are due to the antioxidant property of turmeric and cinnamon (Balasubramanyam *et al.*, 2003 and Lin *et al.* 2003). Reddy and Lokesh (1994) found that curcumin supplementation inhibited lipid peroxidation in rat liver microsomes, erythrocyte membranes and brain homogenates. Moreover, it lowered susceptibility of LDL to

oxidation (Mesa *et al.*, 2000). Ciftci *et al.* (2010) reported that cinnamon oil (1000 ppm) reduced MDA level ( $P \leq 0.05$ ) and increased GSH-Px and catalase (CAT) activities ( $P \leq 0.01$ ) in broiler chickens. These effects are due to the antioxidant property of cinnamon oil (Lin *et al.* 2003). The protective role of essential oils may result from its antioxidative defense mechanism through the induction of antioxidant enzyme activities (Hsu and Liu 2004). Choim Hwang (2005) reported that the intake of medicinal plants in rats results in an increase in antioxidant enzyme activity and a decrease in MDA. Phenolic compounds of essential oils increased the activity of CAT, which in turn detoxifies hydrogen peroxide and converts lipid hydroperoxides to nontoxic substances (Fki *et al.* 2005). In addition, GSH-Px and CAT activity were found to be lower in the antibiotic group compared with the other cinnamon groups and control of the present study ( $P < 0.001$ ). Antibiotics produce different effects on CAT and GSH-Px activities in the organism (Johnson *et al.* 2000). Sukoyan *et al.* (2005) reported that penicillin, amino glycosides and cephalosporins decreased enzyme activity of the glutathione associated antioxidant system, after treatment with antibiotics glutathione peroxidase activity decreased, while catalase activity remained unchanged.

## CONCLUSIONS

Based on experiment findings, we state that cinnamon and turmeric could have beneficial effects on performance, digestibility and were significantly an immunomodulatory and may be play an important role as an exogenous antioxidant.

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### تأثير الاضافة الغذائية للقرفة والكرم على صفات الأداء، صفات الذبيحة، الاستجابة المناعية الامية وميتابوليزم سيرم الدم في الارانب النامية

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استخدم في هذه الدراسة عدد 72 ارناب نامية من كلا الجنسين عمر 5 اسابيع بمتوسط وزن  $25.97 \pm 639.4$ . وزعت الارانب عشوائيا الى 6 معاملات وبكل معاملة 12 ارناب وبكل معاملة 4 مكررات وبكل مكررة 3 ارناب. استمرت التجربة 6 اسابيع. وكانت المعاملات الغذائية كالتالي: (1 مجموعة المقارنة) (عليقة الكنترول)، (2 عليقة الكنترول + 100 مجم مضاد حيوي تيلوسين /كجم علف، 3) عليقة الكنترول + 0.5 جم كركم /كجم علف، (4) عليقة الكنترول + 1 جم كركم /كجم علف، (5) عليقة الكنترول + 0.5 جم قرفة /كجم علف، (6) عليقة الكنترول + 1 جم قرفة /كجم علف. اظهرت النتائج اختلافات معنوية ( $P \leq 0.05$ ) في كلا من وزن الجسم، معدل الزيادة الوزنية، الغذاء المستهلك والكفاءة التحويلية بين المعاملات التجريبية ومجموعة الكنترول. حيث سجلت المجموعتين المعاملتين ب 1 جم كركم او قرفة /كجم علف اعلى قيم لوزن الجسم النهائي ووزن الجسم المكتسب، و افضل معدل التحويل الغذائي. كما سجلت مجموعتي الكنترول والتيلوسين اعلى معدل استهلاك للغذاء بينما سجلت المعاملة بكلا المستويين من القرنة اقل القيم لمعدل استهلاك الغذاء. كما ان اضافة التيلوسين، الكرم والقرفة للعلائق حسنت معنويا ( $P \leq 0.05$ ) من معاملات هضم كلا من المادة الجافة، المادة العضوية، البروتين الخام، الالياف الخام، المستخلص الاثيري والمستخلص الخالي من النتروجين (الكربوهيدرات الذائبة) كما تحسنت القيم الغذائية للعليقة مثل مجموع المواد الغذائية المهضومة و البروتين الخام المهضوم مقارنة بمجموعة الكنترول. عموما ارتفعت معنويا عدد كرات الدم الحمراء وكرات الدم البيضاء وقيم الهيموجلوبين و نسبة خلايا الدم المضغوطة في المعاملات التجريبية المختلفة مقارنة بمجموعة الكنترول مع استثناء عدد كرات الدم البيضاء لارانبمجموعة التيلوسين حيث سجلت انخفاض غير معنوي مقارنة بمجموعة الكنترول. كما لوحظ تحسن صورة دهون سيرم الدم مع الاضافات ( الكرم والقرفة) مقارنة بمجموعتي الكنترول والتيلوسين. انخفض معنويا ( $P \leq 0.05$ ) مستوى الليبيد بيروكسيد وارتفع معنويا تركيز مجموع المواد المضادة للاكسدة و الجلوتاثيون بيروكسيد في المعاملات المحتوية على الكرم والقرفة. كما لوحظ تأثيرات معنوية للاضافات الغذائية على الاستجابة المناعية. ويستنتج من هذه الدراسة ان اضافة كلا من الكرم والقرفة الى عليقة الارانب النامية كان لها تأثير مفيد على الاداء الانتاجي، معاملات الهضم ورفع للمناعة.