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EFFECT OF DIETARY SUPPLEMENTATION OF GARLIC *(ALLIUM SATIVUM)* AND TURMERIC *(CURCUMA LONGA)* ON GROWTH PERFORMANCE, CARCASS TRAITS, BLOOD PROFILE AND OXIDATIVE STATUS IN GROWING RABBITS

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Abstract

This study was performed to investigate the effects of dietary supplementation with garlic and turmeric powder as growth promoter agents on performance, carcass traits, serum biochemistry, and antioxidant enzyme activities of growing rabbits. A total of 112 New Zealand White rabbits (NZW) at 5 weeks of age were randomly assigned to seven treatments with four replicates. The dietary treatments consisted of 7 groups as follows; the basal diet as control, phytogenic additives groups were supplemented with 2, 4, and 6 g/kg garlic or turmeric powder added to the basal diet. There were no linear and quadratic differences (P<0.05) in growth performance after garlic or turmeric supplementation at all studied ages. Compared with the control group, supplementation of diets with garlic or turmeric linearly and quadratically elevated immunity biomarkers such as total protein (TP), albumin (AL) and immunoglobulin (IgG) levels and decreased (linearly and quadratically, P<0.05) aspartate aminotransferase (AST), alanine aminotransferase (ALT), triglyceride (TG) and total cholesterol (TC) levels in rabbit serum. However, TP, AL, globulin (GL), IgG and IgM levels were linearly and quadratically enhanced with increasing turmeric levels versus the control diet. Hepatic superoxide dismutase (SOD), catalase (CAT) and glutathione peroxidase GSH-Px activities as well as reduced glutathione (GSH) concentrations were linearly and quadratically (P<0.05) improved in garlic or turmeric additives fed groups. While MDA concentration was statistically (linearly, P= 0.022) reduced in comparison with the control group. It could be concluded that garlic or turmeric supplementation (2, 4 and 6 g/kg) did not linearly and quadratically affect growth performance but improved the immunity responses and lowered the lipid profile in blood and lipid peroxidation in liver and increased hepatic antioxidant activity in treated rabbits.

Key words: rabbits, phytogenic additives, performance, serum biochemistry, antioxidant status

Supplementation of growth promoters from different sources to rabbit diets is common and widely used in order to improve the utilization of nutrients (Abdel-Wareth et al., 2014; Földešiová et al., 2015). The growth promoters like chemical

products, herbal plants, essential oils, antibiotics, enzymes etc. play an active role in the experimental and commercial production of large and small animals (Ashour et al., 2014; Dhama et al., 2014). Recently, many countries tend to prevent the application of antibiotics for their side effects on both animal and human. 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 (phytogenic extracts) are used very commonly (Ortserga et al., 2008).

Garlic (*Allium sativum*) has been a subject of considerable interest as a medicinal and therapeutic agent worldwide since ancient times (Shetty et al., 2013). Main pharmacological effects of garlic are attributed to its organosulfur compounds (Tapiero et al., 2004). Allicin – the main bioactive component of garlic – may account for some effects of garlic (Amagase et al., 2001). *In vitro* studies have shown that garlic possesses antibacterial, antifungal, antiparasitic, antiviral and antioxidant (Ankri and Mirelman, 1999) properties. It has benefits in lowering total plasma cholesterol, reducing blood pressure and decreasing platelet aggregation (Sterling and Eagling, 2001). A study by Ahmed et al. (2002) pointed out that live body weight, daily weight gain and feed conversion ratio were improved significantly by addition of garlic powder to rabbit diet. Additionally, Onu and Aja (2011) reported that garlic supplementation by 0.25% produced significant ($P<0.05$) effects on weight gain, feed intake and feed conversion ratio and significantly enhanced the hematological parameters of rabbits as well.

Turmeric (*Curcuma longa*) is a medicinal plant widely used and cultivated in tropical regions. Plant extracts were found to have antifungal, immunomodulatory and antioxidative (Farag et al., 2014; Alagawany et al., 2015) as well as antimutagenic (Soni et al., 1997) activities. Turmeric powder is a rich source of beneficial phenolic compounds: the curcuminoids, where three main curcuminoids, curcumin, demethoxycurcumin and bisdemethoxycurcumin (Balasubramanyam et al., 2003) have been isolated from turmeric. Supplementation of turmeric powder at 0.20 and 0.40 g/kg to the commercial diet for rabbits positively affected the body weight gain in rabbit does (Földešiová et al., 2015). On the other hand, Basavaraj et al. (2011) noted that dietary inclusion of turmeric powder at 0, 0.15 and 0.30% had no beneficial impacts on blood parameters and meat characteristics of growing rabbits reared under summer stress. However, information about optimal level of garlic and turmeric powder as growth promoters and natural antioxidants in growing rabbit is scarce. Therefore, the aim of this study was to evaluate the potential of increasing levels of garlic and turmeric powder as phytogenic additives on growth performance, carcass characteristics, serum biochemical metabolites and antioxidant enzyme activities in growing rabbits.

Material and methods

Animals, experimental design and diets

The present investigation was carried out at Rabbit Research Farm, Department of Poultry, Faculty of Agriculture, Zagazig University, Egypt. All experimental pro-

cedures were carried out according to the Local Experimental Animal Care Committee, and approved by the ethics of the institutional committee of Department of Poultry, Faculty of Agriculture, Zagazig University, Zagazig, Egypt.

Table 1. Formulation and composition of commercial growing rabbit diet

Ingredient	Basal diet
Yellow corn	20.00
Soybean meal 44%	20.00
Wheat bran	16.00
Berseem hay	30.00
Barley grain	10.00
Molasses	2.00
Limestone	1.00
Salt	0.50
Premix*	0.50
Total	100
Analyzed composition (%)**:	
crude protein	16.54
ether extract	2.25
crude fiber	12.33
dry matter	88.06
organic matter	90.57
nitrogen free extract	59.45
calcium	0.88
phosphorus	0.49
ash	9.44
neutral detergent fiber	32.00
acid detergent fiber	18.1
acid detergent lignin	4.00
starch	17.50
calcium/phosphorus	1.79
digestible energy (kcal/kg)	2585

*Premix provided per kg of complete diet: vitamin A, 12,000 IU; vitamin D_3, 1000 IU; vitamin E acetate, 50 mg; vitamin K_3, 2 mg; biotin, 0.1 mg; thiamin, 2 mg; riboflavin, 4 mg; vitamin B_6, 2 mg; vitamin B_{12}, 0.1 mg; niacin, 40 mg; pantothenic acid, 12 mg; folic acid, 1 mg; choline chloride, 300 mg; iron, 100 mg; copper, 20 mg; magnesium, 50 mg; cobalt, 2 mg; iodine, 1 mg; zinc, 100 mg; selenium, 0.1 mg.

**Determined according to AOAC (1990).

A total of one hundred and twelve NZW growing rabbits after weaning at 5 wk of age with initial body weight of 625.71±2.94 g were purchased from a commercial breeder. Rabbits were randomly allocated to 7 treatment groups, each of which included 4 replicates of 4 rabbits. The experiment lasted for 8 wk to be finished at 13 wk of age and dietary treatments were as follows: 1) control (basal diet); 2) basal diet + 2 g/kg garlic; 3) basal diet + 4 g/kg garlic; 4) basal diet + 6 g/kg garlic; 5) basal diet + 2 g/kg turmeric; 6) basal diet + 4 g/kg turmeric; and 7) basal diet + 6 g/kg turmeric. Rabbits were housed in galvanized wire cages (40 cm high × 30 cm wide × 50 cm long) and fresh water was automatically available all the time. All

rabbits were kept under the same managerial, hygienic and environmental conditions. Rabbits were fed to cover their requirements according to NRC (1977). The garlic and turmeric powder were obtained from Free Trade Egypt Company (Behira, Egypt). All the diets with tested herbal plants were pelleted and stored in the rabbit farm throughout the experimental period. The formulation and composition of commercial rabbit diet is shown in Table 1.

Growth performance

Live body weight (LBW) and feed intake (FI) of rabbits were recorded by pen at biweekly intervals, and average daily feed intake (ADFI), body weight gain (BWG) and feed to gain ratio (FCR) were calculated from these data by period and cumulatively. Feed wastage was recorded daily and the data were used to estimate feed consumption.

Carcass measurements

At the end of the experiment, the rabbits from each group were weighed and slaughtered without fasting. The carcasses were prepared by removing the skin, feet, paws, genital organs, urinary bladder and digestive tract. Hot carcass weight (the main body, head, kidneys, liver, heart, lungs and other total edible parts) were determined according to Blasco et al. (1993). The carcasses were weighed and the weights of the skin, legs, liver, spleen, kidneys, heart and lungs were recorded and expressed as g/kg of slaughter weight (SW). Carcass percentage = carcass weight*100/live body weight. Dressing percentage = (carcass weight plus giblets weight)*100/live body weight.

Serum biochemistry

At the end of experimental period, blood samples were collected from sacrificed rabbits in clean sterile tubes. Samples were let to coagulate and centrifuged at 3500 rpm for 15 minutes and serum was separated and stored at –20°C till analyzed. The following serum biochemical parameters: total protein (TP), albumin (AL), globulin GL (TP-AL), total cholesterol (TC), high density lipoprotein (HDL), low-density lipoprotein (LDL), triglyceride (TG), aspartate aminotransferase (AST) and alanine aminotransferase (ALT), immunoglobulin G (IgG) and M (IgM) levels were estimated in serum using commercial biodiagnostic kits provided from Biodiagnostic Company (29 El-Tahrir St. Dokki, Giza, Egypt) and a spectrophotometer (Shimadzu, Japan).

Assay of Antioxidant Indices in liver

For antioxidant assays, liver samples from six rabbits / treatment were homogenized (10% w/v) in potassium phosphate buffer solution (pH 7.4) then centrifuged at 3000 rpm for 15 min. Then the obtained supernatants were subjected to the measurement of superoxide dismutase (SOD), catalase (CAT) and glutathione peroxidase (before GSH-Px) activities as well as reduced glutathione (GSH) and malondialdehyde (MDA) levels by using commercial kits obtained from Biodiagnostic Company (29 El-Tahrir St. Dokki, Giza, Egypt) and a spectrophotometer (Shimadzu, Japan).

Activity of SOD was measured by the xanthine oxidase method, which monitors the inhibition of reduction of nitro blue tetrazolium by the sample (Winterbourn et al., 1975). Activity of CAT in supernatant was determined according to the method of Aebi (1984) by monitoring the initial rate of disappearance of hydrogen peroxide (initial concentration 10 mmol) at 240 nm in a spectrophotometer. Results were reported as rate constant per second per milligram tissue (nmol/g tissue). Activity of GSH-Px was detected with 5, 5′-dithiobis-p-nitrobenzoic acid, and the change of absorbance at 412 nm was monitored spectrophotometrically (Hafeman et al., 1974). GSH concentration was analyzed by the method of Beutler et al. (1963). The MDA level was analyzed with 2-TBA, monitoring the change of absorbance at 532 nm with the spectrophotometer (Jensen et al., 1997).

Statistical analysis

The experiment was carried out as a completely randomized design. The performance, carcass characteristics, serum biochemical metabolites and antioxidant enzyme activities were evaluated by means of the GLM procedure of SAS (SAS Institute Inc., 2001). Orthogonal polynomial contrasts were used to test the linear and quadratic effects of the increasing levels of supplementation of garlic and turmeric powder.

Results

Growth performance and carcass measurements

The effects of dietary phytogenic additives supplement on growth performance of rabbits during the experiment are shown in Table 2. There were no linear or quadratic differences ($P<0.05$) in LBW, BWG, FI and FCR due to garlic or turmeric treatments at all studied ages. Table 3 summarizes the impact of treatments on carcass characteristics at wk 13 of age. Compared with the control diet, carcass weight and yield as well as spleen and dressing percentages of rabbits were not statistically (linearly and quadratically, $P<0.05$) influenced by the dietary garlic treatments at the end of the experiment (13 wk of age). Garlic addition to rabbit diets resulted in a significant linear decrease in liver ($P=0.003$), lungs ($P=0.015$), giblets ($P=0.002$), skin and legs ($P<0.001$) weights compared with the non-supplemented group. However, relative kidney weight decreased linearly and quadratically ($P=0.002$ and 0.013, respectively) with increasing the dietary garlic level where the highest value of kidney weight was obtained at 2 g/kg diet.

In the present study, dietary supplementation of turmeric did not have linear or quadratic effects on carcass yield, liver, spleen and giblets weights of growing rabbits at 13 wk of age. On the other hand, diets supplemented with turmeric linearly decreased kidney ($P=0.014$), skin and legs weights ($P=0.032$) as well as dressing percentage ($P=0.037$) of rabbits. While increasing the dietary turmeric level to 6 g/kg, significantly increased relative heart weight (linearly and quadratically, $P=0.021$ and < 0.001, respectively), carcass weight (quadratically, $P=0.017$), in addition to quadratic increase ($P=0.019$) in relative lung weight ($P=0.019$) with 4 g/kg of turmeric powder compared with the control group.

Table 2. Effects of garlic and turmeric powder on growth performance of NZW growing rabbits during experimental period

Parameters	Garlic and turmeric powder (g/kg of basal diet, BD)												
	BD	Garlic levels (g)			SEM[1]	P-value[2]		Turmeric levels (g)			SEM[1]	P-value[2]	
		2	4	6		linear	quadratic	2	4	6		linear	quadratic
Live body weight (g) at													
5 wk	630	621	629	625	4.40	0.877	0.832	625	627	623	4.92	0.703	0.967
9 wk	1498	1500	1580	1512	38.26	0.487	0.845	1494	1495	1542	29.68	0.658	0.479
final (13 wk)	1997	2086	2148	2155	75.50	0.358	0.553	2083	2042	2100	49.29	0.856	0.620
Body weight gain (g)													
5–9 wk	31.01	31.37	33.96	31.68	1.32	0.462	0.861	31.05	31.01	32.82	0.97	0.574	0.429
9–13 wk	19.27	20.93	20.31	22.96	1.91	0.653	0.574	19.94	19.53	19.94	1.67	0.207	0.082
overall (5–13 wk)	25.41	26.15	27.13	27.85	1.34	0.837	0.892	25.85	25.27	26.38	1.17	0.689	0.416
Daily feed consumption (g)													
5–9 wk	70.65	70.88	69.16	71.68	1.95	0.399	0.147	67.65	66.80	72.07	1.96	0.380	0.064
9–13 wk	71.85	68.04	67.22	74.07	4.46	0.387	0.592	70.75	73.55	70.77	3.87	0.863	0.603
overall (5–13 wk)	71.26	69.46	68.19	72.87	2.59	0.341	0.554	71.05	70.17	71.42	2.58	0.927	0.873
Feed conversion ratio (g feed/ g gain)													
5–9 wk	2.27	2.25	2.03	2.43	0.08	0.947	0.295	2.17	2.15	2.19	0.10	0.736	0.212
9–13 wk	3.72	3.25	3.30	3.22	0.45	0.209	0.469	3.54	3.76	3.54	0.49	0.811	0.601
overall (5–13 wk)	2.81	2.65	2.66	2.61	0.25	0.573	0.921	2.47	2.77	2.81	0.25	0.466	0.436

[1]SEM = Standard Error Means.
[2]Linear and quadratic effects.

Table 3. Effects of garlic and turmeric powder on carcass yield and proportions of various carcass parts and organs of NZW growing rabbits (n=6 for each group) at 13 wk of age

Parameters	Garlic and turmeric powder (g/kg of basal diet, BD)												
	BD	Garlic levels (g)			SEM[1]	P-value[2]		Turmeric levels (g)			SEM[1]	P-value[2]	
		2	4	6		linear	quadratic	2	4	6		linear	quadratic
Slaughter weight (SW) (g)	1990	2077	2150	2152	50.25	0.081	0.661	2078	2048	2090	27.15	0.075	0.070
Carcass weight (g)	1020	1025	1191	1201	28.81	0.060	0.322	1015	1071	1152	20.82	0.885	0.017
Carcass yield (%)	51.25	53.14	54.82	57.18	0.83	0.457	0.166	52.25	53.78	53.85	0.53	0.091	0.101
Heart (g/kg SW)	2.79	2.85	2.32	3.15	0.11	0.422	0.045	2.33	2.69	3.29	0.10	0.021	<0.001
Kidney (g/kg SW)	6.88	7.04	6.72	5.70	0.17	0.002	0.013	6.45	6.39	5.76	0.52	0.014	0.194
Liver (g/kg SW)	34.84	31.60	28.09	28.98	1.06	0.003	0.082	30.32	34.04	30.68	6.02	0.396	0.797
Spleen (g/kg SW)	0.90	0.65	0.67	0.65	0.06	0.259	0.411	0.57	0.64	0.52	0.07	0.069	0.756
Lungs (g/kg SW)	7.56	6.52	6.05	5.74	0.31	0.015	0.345	8.92	11.65	5.72	0.76	0.921	0.019
Skin and legs (g/kg SW)	215	205	204	184	3.62	<0.001	0.109	209	186	161	8.70	0.032	0.118
Giblets (%)	4.55	4.15	3.71	3.78	0.11	0.002	0.116	3.91	4.31	3.98	0.18	0.347	0.727
Dressing (%)	60.40	57.30	58.53	60.96	0.86	0.707	0.153	56.17	58.10	57.83	0.57	0.037	0.066

[1]SEM = Standard Error Means.
[2]Linear and quadratic effects.

Table 4. Effects of garlic and turmeric powder on blood profiles in NZW growing rabbits (n=6 for each group) at 13 wk of age

Parameters	Garlic and turmeric powder (g/kg of basal diet, BD)												
	BD	Garlic levels (g)			SEM[1]	P-value[2]		Turmeric levels (g)			SEM[1]	P-value[2]	
		2	4	6		linear	quadratic	2	4	6		linear	quadratic
TP (g/dl)[3]	5.25	6.29	6.14	5.88	0.21	0.030	0.019	6.05	6.74	6.25	0.37	0.812	0.003
AL (g/dl)	2.41	2.48	2.98	2.91	0.13	0.025	0.001	2.50	3.13	3.49	0.14	0.003	0.013
GL (g/dl)	2.84	3.81	3.16	2.97	0.19	0.148	0.351	3.54	3.61	3.76	1.26	0.016	0.059
ALT (IU/ml)	42.80	36.05	36.62	37.61	0.89	0.007	0.002	34.12	33.02	31.26	1.43	<0.001	0.554
AST (IU/ml)	51.62	51.07	49.38	47.64	0.58	0.006	0.495	40.57	38.60	37.99	1.70	<0.001	0.038
TG (mg/dl)	189	124	112	118	9.32	<0.001	<0.001	150.81	129.43	128.88	7.56	<0.001	0.863
TC (mg/dl)	103	97.56	96.06	91.16	1.29	<0.001	0.526	90.50	85.63	89.27	2.14	<0.001	0.084
HDL (mg/dl)	38.67	39.69	45.66	45.19	2.45	0.315	0.893	42.02	47.44	54.31	3.24	0.144	0.388
LDL (mg/dl)	61.73	57.02	47.00	48.28	3.02	0.946	0.534	55.92	51.79	39.65	3.02	0.003	0.008
IgG (mg/dl)	1.67	2.14	2.36	2.60	0.15	<0.001	<0.001	1.91	2.58	3.15	0.23	0.006	0.736
IgM (mg/dl)	12.75	13.99	13.76	14.00	0.24	0.095	0.261	18.69	16.76	15.75	0.98	0.379	0.008

[1]SEM = Standard Error Means.

[2]Linear and quadratic effects.

[3]TP: total protein, AL: albumin, GL: globulin, ALT: alanine aminotransferase, AST: aspartate aminotransferase, TG: triglyceride, TC: total cholestrol, HDL: high density lipoprotein, LDL: low density lipoprotein, IgG and IgM: immunoglobulin G and M.

Table 5. Effects of garlic and turmeric powder on oxidative status in liver of NZW growing rabbits at 13 wk of age

Parameters	Garlic and turmeric powder (g/kg of basal diet, BD)												
	BD	Garlic levels (g)			SEM[1]	P-value[2]		Turmeric levels (g)			SEM[1]	P-value[2]	
		2	4	6		linear	quadratic	2	4	6		linear	quadratic
Oxidative status[3]:													
SOD (U/ ml)	130	209	190	183	8.90	<0.001	<0.001	145	203	184	11.78	0.023	0.628
CAT (nmol/g tissue)	27.99	57.98	63.67	40.87	4.61	0.047	<0.001	29.48	41.19	58.12	3.80	<0.001	<0.001
GSH-Px (Mmol/min/ml)	138	198	205	174	8.19	0.001	<0.001	171	188	220	8.90	<0.001	<0.001
GSH (ng/ g tissue)	6.51	6.58	9.85	7.26	0.47	0.042	0.039	6.67	6.76	9.90	0.43	<0.001	<0.001
MDA (nmol/mL)	6.69	4.24	4.11	3.07	0.54	0.022	0.438	4.43	4.27	2.83	0.43	<0.001	0.253

[1]SEM = Standard Error Means.
[2]Linear and quadratic effects.
[3]SOD: superoxide dismutase, CAT: catalyse, GSH-Px: glutathione peroxidase, GSH: reduced glutathione, MDA: malondialdehyde.

Serum biochemistry

The effect of garlic and turmeric supplementation on serum biochemical parameters of rabbits are shown in Table 4. All studied blood constituents were significantly ($P<0.05$) influenced by garlic supplementation except GL, IgM, HDL and LDL. Compared with the control group, supplementation of diets with garlic linearly and quadratically elevated TP, AL and IgG concentrations and decreased ALT, AST, triglyceride and total cholesterol levels in rabbit serum both linearly and quadratically ($P<0.05$). Turmeric inclusion statistically influenced serum biochemical metabolites except HDL (Table 4). Where, ALT, AST, TG, TC and LDL concentrations were linearly and quadratically decreased with increasing the dietary proportion of turmeric. However, TP, AL, GL and immunoglobulin G and M levels were linearly and quadratically enhanced with increasing turmeric levels versus the control diet.

Antioxidant Indices in liver

The effects of garlic and turmeric supplementation on the antioxidant parameters including liver activities of SOD, CAT, GSH, GSH-Px and MDA of growing rabbits were illustrated in Table 5. In general, hepatic SOD, CAT and GSH-Px activities as well as GSH concentration were linearly and quadratically ($P<0.05$) improved in garlic additives fed groups. While MDA concentration was statistically (linearly, $P=0.022$) reduced in comparison with the control group, which was minimized at 6 g/kg diet. Animals fed diets supplemented with turmeric powder showed greater (linear and quadratic, $P<0.001$) activities of hepatic CAT, GPx and GSH compared with those in control animals at 13 wk of age. However, increasing dietary turmeric supplementation led to increased SOD activity and decreased MDA concentration (linearly, $P=0.023$ and <0.001, respectively).

Discussion

The present study was conducted to evaluate the beneficial roles of garlic and turmeric as natural feed additives on performance, carcass traits, blood constituents and liver oxidative status of growing rabbits. Dietary phytogenic additives did not affect growth performance indices. These results agreed with studies conducted by Quiles et al. (2002) and Peiretti et al. (2010) who found that the growth performance parameters of growing rabbits were not affected by dietary curcuma supplementation. The results obtained for turmeric are in concurrence with Ramirez-Tortosa et al. (1999) and Basavaraj et al. (2010) who reported that turmeric supplementation did not affect the BWG or FI of rabbits. Addition of turmeric powder at 2 and 4% to the commercial diet for rabbit positively affected body weight gain in rabbit does (Földešiová et al., 2015).

Supplemental dietary garlic or turmeric up to 0.6% in rabbit diets led to numerical improvement in LBW at 9 and 13 wk of age. This improvement in LBW with phytogenic additives supplementation 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 allicin) found in turmeric and garlic that cause greater efficiency in the utilization of feed, resulting in enhanced growth. Our results partially agree with Gbenga et al. (2009) who indicated that BWG, FI and FCR were not statistically influenced by dietary garlic supplementation; just a marginally higher BWG was observed in animals consuming garlic supplemented diets at high concentration than those fed the basal diet. Adibmoradi et al. (2006) found that garlic supplementation (5 to 20 g/kg) positively affected histological structure of the gastrointestinal tract, which may increase the nutrient digestion and uptake, thereby enhancing the productive performance.

The results obtained from this study revealed that dietary garlic treatments did not affect carcass weight and yield as well as spleen and dressing percentages of rabbits. These results were in partial agreement with Gbenga et al. (2009) who showed that carcass and organ traits were not significantly influenced by dietary garlic supplementation. In the same context, Raeesi et al. (2010) elucidated that garlic at 1 or 3% had no significant effects on relative weights of carcass or digestive organs among treatments. On the other hand, a study by Peiretti et al. (2010) revealed that the dressing proportions at the end of experimental period of growing rabbits were not affected by dietary turmeric supplementation. Similarly, Basavaraj et al. (2011) pointed out that there were no beneficial impacts of dietary inclusion of turmeric powder at 0, 0.15 and 0.30% on blood parameters and meat characteristics of growing rabbits reared under summer stress. Contradicting results in carcass traits of farm animals obtained by the previous authors may be also due to the different doses of herbal plant, duration of experimental period, number of experimental animals, animal age, etc., that may be attributed to the amount of bioactive components such as curcuminoids, curcumin and allicin present in turmeric and garlic herbs.

Biochemical blood parameters are usually related to health status. These parameters are good indicators of physiological, pathological, and nutritional status of animals and have the potential of being used to elucidate the impact of nutritional factors and additives supplied in diet. Dietary supplementation of garlic to basal diet exhibited a significantly positive effect on TP, AL and lipid profile which is in accordance with Konjufca et al. (1997). On the contrary, Toghyani et al. (2011) noted that garlic supplementation did not induce any significant effect on the serum concentration of protein and albumin. Interestingly, in line with our observations on lipid profile, Yalçin et al. (2006) found that serum cholesterol levels were significantly ($P<0.05$) reduced by garlic addition to growing rabbit diets. Qureshi et al. (1993) reported that diets containing an equivalent of 1, 2, 4, 6, and 8% garlic paste reduced blood cholesterol by 18, 21, 21, 24 and 25% respectively. The reduction of serum cholesterol observed when garlic paste was fed could be returned to the reduction of synthetic enzyme activity as suggested by Chowdhury et al. (2002). Sher et al. (2012) observed that the rabbits fed diets supplemented with garlic extract by 250, 300 or 350 mg/kg body weight had lower ($P<0.05$) TC, TG and LDL.

Our results were consistent with some other studies which demonstrated that garlic supplementation could induce a positive effect on cholesterol metabolism (Kim et al., 2009; Yan et al., 2011). That in turn would reflect on the health status because concentrations of TG, TC and LDL may induce the development and progression of

cardiovascular diseases. Therefore, the decrease in LDL could also mirror the oxidative effects of garlic.

In the present study, lipid parameters (TG, TC and LDL concentrations) were significantly decreased with increasing turmeric. These results for lipid profile concentrations agree with Quiles et al. (2002) and Wientarsih et al. (2002) who noted that *Curcuma longa* supplementation to the rabbit diets statistically decreased LDL, TC and TG 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 TC biosynthesis in rat cells (Amin et al., 1993).

Supplementation of 4 g/kg of turmeric was enough to reduce serum TC. However, addition of 6 g/kg of turmeric did not further affect serum TC levels. Turmeric supplementation resulted in improving the lipid profile of rabbits. This was in agreement with Hussein (2013) who clearly demonstrated that TG and TC were statistically decreased with increasing turmeric levels to 7 g/kg diet. The reduction of lipids profile (TG, TC and LDL) may be due to curcumin that enhances bile production and hence lipid digestion (Al-Sultan and Gameel, 2004).

Serum HDL levels were not influenced by garlic or turmeric supplements, these results confirm a previous study conducted by Ao et al. (2010) who reported that there were no significant differences in HDL ($P<0.05$) due to garlic supplementation. In our study, supplemental dietary garlic or turmeric up to 0.6% in control diet led to numerically increased HDL concentration.

TC, HDL, LDL, TG and TP did not significantly change in growing rabbits fed *Curcuma longa* (Basavaraj et al., 2011). These effects may be due to the concentration of curcumin in turmeric, because it affects the metabolism of TC, reduced plasma LDL significantly and decreased liver TC content along with an increase of plasma α-tocopherol level in rat. Lowering TC effects may be mediated by the stimulation of hepatic cholestrol-7-hydroxylase activity as TG digestibility was not affected by curcumin addition (Asai et al., 1999).

In animal production, it is very important to improve immunity in order to prevent infectious diseases. A variety of factors such as failure in vaccination and abuse of antibiotics can induce immunodeficiency and infection by immune-suppressive diseases. Use of immune stimulators is one solution to enhance immunity and to decrease susceptibility to infectious diseases. Herbal plants that are rich in flavonoids such as garlic and turmeric extend the activity of vitamin C, act as antioxidants, and may therefore improve immune functions (Acamovic and Brooker, 2005). This could explain the effects of treatments on immune related parameters which are presented in Table 4. Serum IgG and IgM were enhanced ($P<0.05$) in animals fed diets containing phytogenic additives. Garlic and turmeric addition may improve the immune system due to the increase in the immunoglobulin concentrations (IgG and IgM) of rabbits that consumed herbal plants treatments versus the control diet. It is likely that a higher dosage of natural herbal feed additives may be needed to stimulate humoral immune response. Previous studies have found that garlic and their contents could activate the immune function such as lymphocyte proliferation,

cytokine release, phagocytosis and killer cell activity (Wang et al., 2011). In addition, it was suggested that garlic as natural antibiotic or allicin addition exerted positive effects on young animals mainly attributed to the improvement in immunity (Wang et al., 2011). These positive effects of using garlic and turmeric might be due to their anti-inflamatory, antioxidant and antibacterial activities. Thus, turmeric and garlic are suggested to limit the growth and colonization of numerous pathogenic and non-pathogenic species of bacteria in the rabbit's gut and balanced gut microbial ecosystems leading to better feed utilization (Nouzarian et al., 2011).

Enhanced concentrations of serum AST and ALT are used as indicators of liver damage (Ozaki et al., 1995), the activities of AST and ALT reduced in rabbits fed diet supplemented with garlic or turmeric compared to the control group suggesting the hepatoprotective effect of turmeric.

In the current experiment, feeding the animals on garlic and turmeric supplemented diet improved the hepatic antioxidant enzymes and reduced the MDA concentration in comparison with the control group. The same results were reported by Lin et al. (2003) who found that the intake of herbs resulted in an increase in serum antioxidant enzyme activities and a decrease in MDA concentration. On the contrary, Konjufca et al. (1997) found that the concentration of blood reduced glutathione was not affected by dietary garlic ($P>0.52$). Our findings are also supported by Benzie and Wachtel-Galor (2011) who reported that turmeric extracts can scavenge free radicals, increase antioxidant enzymes, and inhibit lipid peroxidation, whereas 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. SOD "metalloprotein enzyme" is the first enzyme contributed in the antioxidant defense system. 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.

The concentration of liver MDA is an indicator for evaluating antioxidant systems. Compared with the control group, animals fed 2, 4 or 6 g/kg of turmeric or garlic had significantly lower liver concentration of MDA ($P<0.05$). The prevention of lipid oxidation (MDA) in muscle-based foods can be achieved by the supplementation of natural antioxidants, such as garlic and turmeric, as dietary supplements. 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. The results of the present study show that both garlic and turmeric diets reduce the oxidative reactions in the rabbit body and production rate of lipid peroxidation. It could improve the meat quality via the reduction of peroxides and free radicals. Also, the previous authors noted that the rabbit diet without curcuma supplementation showed significantly higher plasma lipid peroxide at all experimental periods (10, 20, and 30 d) compared to the curcuma diets.

Supplementation of basal diet with garlic 4 g or turmeric 6 g/kg could equally improve liver GSH in rabbits, compared to the other groups. 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 the natural additives as garlic or turmeric could be applied in the future to improve the nutritional quality of animal meat.

It seems that turmeric and garlic supplementation to control diet was effective in enhancing the antioxidant ability of animals. Since turmeric is a rich source of beneficial phenolic compounds, the curcuminoids have strong antioxidant activity (Balasubramanyam 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). Based on these findings, we state that garlic and turmeric might play an important role as an exogenous antioxidant and could also be applicable as a protective agent against tissue damage.

Conclusions

In view of the above findings and discussion, we concluded that garlic or turmeric supplementation (2, 4 and 6 g/kg) did not linearly and quadratically affect growth performance but improved the immunity responses; in addition, rabbits fed diet supplemented with medicinal plant garlic or turmeric had lower lipid profile in blood and lipid peroxidation in liver and increased hepatic antioxidant activity.

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