PRODUCTIVE PERFORMANCE, CARCASS TRAITS, LIPID PROFILE, ANTIOXIDANTS AND IMMUNITY OF GROWING RABBITS TREATED WITH GUM ARABIC UNDER EGYPTIAN SUMMER CONDITION

I.T. El-Ratel[1*], Rehab F. S. A. Ismail[2] and Sara F. Fouda[3]

[1]*Department of Poultry Production, Faculty of Agriculture, Damietta University, Damietta, Egypt*

[2]*Department of Animal Production, Faculty of Agriculture, Mansoura University, Mansoura, Egypt*

[3]*Department of Poultry Production, Faculty of Agriculture, Mansoura University, Mansoura, Egypt*

* ***Author for correspondence:*** **El-Ratel, I.T**, *E-mail:* ibrahim.talat81@yahoo.com

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SUMMARY

Effect of Gum Arabic (GA), as natural antioxidant in the diet, on growth, carcass, digestibility, liver and kidney functions, antioxidant capacity, immunity, thyroid and testosterone hormones of growing rabbits was studied under Egyptian hot condition. Male APRI line rabbits (n=90) were assigned into 3 groups fed basal diet with 0 (T1), 1 (T2) and 2 (T3) kg GA/ton. Growth performance parameters and viability rate were recorded at age intervals from 5 to 11 wk. Digestibility coefficients, carcass traits, serum biochemicals, antioxidant, immunity, and thyroid and testosterone hormones were determined at 11 wk of age. Results revealed that GA addition increased (P<0.05) growth performance, carcass traits (hind parts and dressing), serum total proteins, albumin, globulin, high-density lipoproteins, glucose, total antioxidant capacity, immunoglobulins, triiodothyronine, tetraiodothyronine and testosterone concentrations. Relative weight of carcass foreparts, weight of full digestive tract, cholesterol, triglycerides and low-density lipoproteins, hepato and renal somatic indexes, urea and malondialdehyde decreased (P<0.05) as affected by GA. In conclusion, dietary supplementation with both levels of GA can enhance productive performance, lipid profile, immune response and antioxidant defense system of growing rabbits under Egyptian summer conditions. The best results were obtained with adding 2 kg GA/ton diet.

Keywords: Rabbits, Arabic gum, growth performance, antioxidant status and immunity.

INTRODUCTION

The major threats for progress of rabbit industry are global warming and climate change (El Saidy *et al.*, 2016). The thermo-neutral zone (comfortable zone) of rabbits was reported to be from 18 to 21°C (Al-Zafry and Medan, 2012). Under hot condition in Egypt, the heat stress (HS) is associated with high relative humidity (≥ 85%) during the day time and may be 100% at the night time (Marai *et al.*, 2007). In rabbits, HS induces alterations in energy, water and mineral balances as well as blood characteristics and hormonal levels (Al-Zafry and Medan, 2012), which adversely affect their growth performance, reproductive efficiency and immune response (Finzi et al., 2010; Aggarwal and Upadhyay, 2013). Also, lipid oxidant, as a consequence of increasing generation of free radical and increasing reactive oxygen species (ROS), induce oxidative stress in heat stressed rabbits (Hassan *et al.*, 2016). Additionally, chronic HS may reduce metabolic oxidation capacity due to a self-propagating scavenging system (Azad et al., 2010).

Many *in vivo* studies confirmed that dietary natural antioxidant supplementation is important in ameliorating impacts of HS (McKee and Harrison, 2013). To generate a suitable environment for free radicals withdrawal by antioxidants, a balance in the animal physiological activities is required (Imik *et al.*, 2010). In this respect, Gum Arabic (GA), green tea, curcumin, as natural plant antioxidants, have paid great interest from livestock producers (Basavaraj *et al.*, 2011; El-Ratel *et al.*, 2017). These antioxidants can be used with ease at a low price to the daily diet without adverse effects (Tawfeek *et al.*, 2014).

The GA is an edible, dried sticky exudate obtained from stems and branches of *Acacia seyal* and *Acacia Senegal* and rich in non-viscous soluble fibers (Abdelkareem *et al.,* 2016). It is a complex polysaccharides of high molecular weight, containing neutral and acids sugars such as rhamnose, arabinose, galactose and glucuronic acid (Wyasu and Okereke, 2012), and minerals like Ca, Mg, K, Na and P (Patel and Goyal, 2015). The GA is widely used in the industry of pharmacology and foods, as an emulsifier and stabilizer (Ayaz *et al.*, 2017). In Arabic folk, GA is used medically in patients who suffer with chronic renal failure (Al-Majed *et al.*, 2002). Also, GA is characterized by various biological effects, including nephro-protecting activity and different properties as antioxidant, antibacterial, antiviral, and anti-inflammatory (Jaafar *et al.*, 2016).

The antioxidant properties of GA are documented in a variety of animal model system by Rehman *et al.* (2004). The GA as antioxidant contains phyto-constituents, including flavone, catechin, polyphenols, tannins, chalcones, alkaloids and flavonoids (Pal *et al.*, 2014). These compounds have the ability to remove the free radicals, antioxidant enzymes activation and oxidases inhibition (Ali *et al*., 2009). Also, GA increases nitrogen excretion in feces and lowers urea-nitrogen concentration in blood serum of patients severing from chronic renal failure (Bliss *et al.*, 1996). Furthermore, enhancement in the productive performance of growing rabbits fed diet with GA supplementation was reported by Amber *et al.* (2017). So far, little evidence is yet available regarding the evaluation the potential beneficial role of GA in growth parameters and physiological status of heat stressed rabbits.

Therefore, the current study aimed to investigate the effect of dietary supplementing different levels of Gum Arabic (0, 1 and 2 kg/ton diet) as antioxidants on growth performance, carcass traits, digestibility coefficients, liver and kidney functions, antioxidant capacity, immune response, thyroid and testosterone hormones in growing rabbits reared under hot climatic condition in Egypt.

MATERIALS AND METHODS

The current experiment was conducted at Experimental Rabbitary Farm, and Physiology and Biotechnology Laboratory, Animal Production Department, Faculty of Agriculture, Mansoura University, Egypt, during the period from July to September 2017.

Total of 90 male APRI line rabbits (Egyptian line selected for litter weight at weaning according to Abou Khadiga *et al.* (2010) weaned at 5 weeks of age was used in this study. Throughout an experimental period from 5 to 11 weeks of age, rabbits were housed individually in galvanized wire cages (35 × 35 × 60 cm). Rabbits were kept under the same managerial conditions. Rabbits were fed *ad. libitum* and sufficient feeds were daily offered at 7 a.m., while water was available through cage nipple.

All experimental rabbits were assigned randomly into 3 similar groups, 30 animals in each group. Rabbits in the 1st treatment (T1) were fed a commercial pelleted diet without any supplementation (control diet), while animals in the second (T2) and third (T3) treatment were fed the control diet supplemented with 1 and 2 kg GA/ton diet, respectively. The control diet was formulated to cover the recommended nutrient requirements of growing rabbits according to NRC (1977) as shown in Table (1). Chemical composition of the control diet and GA based on dry matter (DM) was carried out according to the standard methods of AOAC (2012) and presented in Table (2).

Table (1): Ingredients of the control diet used for feeding rabbits in the experimental treatments.

Ingredient	(%)	Ingredient	(%)
Berseem hay	33.0	Limestone	1.0
Barley grain	24.6	DL-Methionine	0.2
Wheat brain	21.5	Sodium chloride	0.5
Soybean meal	17.0	Minerals ([1])	0.15
Molasses	0.3	Vitamins ([2])	0.15
Di-calcium phosphate	1.6	Total	100

1) Each 1kg contains on Vitamin A (150, 000 UI),Vitamin E (100 mg), Vitamin B1(10 mg), Vitamin K3 (21mg), VitaminB2 (40mg), Vitamin B6 (15mg), Vitamin B12 (0.1mg), Pantothenic acid (100 mg) Niacin (200 mg), Biotin (0.5mg), Folic acid (10mg) and Choline chloride (5000 mg). 2) Each 1kg contains on manganese (800 mg), zinc (600mg), iron (300 mg), copper (40m g), iodine (500 mg), selenium (100 mg), and cobalt (100 mg).

Table (2): Chemical analysis of the control diet and Gum Arabic.

Item	Control diet	Gum Arabic
Dry matter (%)	85.8	87.0
Chemical analysis (on DM basis, %):		
Crude protein	17.36	3.71
Crude fiber	13.45	7.98
Ether extract	1.61	0.43
Nitrogen free extract	61.77	85.15
Ash	5.81	2.73
Digestible energy (kcal/ kg)	2412	1387

During the experimental period, live body weight and feed intake were weekly recorded, then average daily weight gain, feed intake and feed conversion ratio were calculated at age intervals of 5-8, 8-11 and 5-11 wk. Also, dead rabbits were recorded, then viability rate was computed during the entire length of the experimental period (5-11 wk). All rabbits were weighed in the morning before offering additional feeds, while daily feed intake was recorded by subtracting weight of the residual amounts of feed from the offered feed before putting the new ones at 7 a.m.

At the last week of the experimental period, 5 rabbits from each group were randomly chosen and individually housed in metabolic cages for 7 days digestibility trial, 4 days adaptation period and 3 days for feed intake determination and collection of feces in the morning (7 a.m.) and evening (7 p.m.). The daily collected feces from each rabbit were freshly weighed, then the feces of three collection days was pooled for each rabbit, then 50% subsample was taken for each rabbit. Feces were oven dried at 60 °C for 24 h, and stored for chemical analysis according AOAC (2012).

After the termination of growing period (5-11 wk of age), other five rabbits (not used in digestibility trails) from each group were randomly chosen, fasted for 12 h, individually weighed and immediately slaughtered to estimate some carcass traits. Net carcasses weight was recorded after bleeding and rabbits, being skinned and eviscerated. Weights of inedible organs (pelt distal leg and full digestive tract) was calculated relative to pre-slaughtered weight, while weights of carcass parts (fore, loin and hind) and edible organs (head, lunges, heart, liver and kidneys) were calculated relative to carcass plus edible organs weight. Dressing rate was calculated by dividing the carcass plus edible organs weight on pre-slaughter weight. Hepato and renal somatic indices were recorded as absolute weight of each organ relative to pre-slaughtered weight. Immediately after slaughtering, meat samples were taken from hind carcass parts of each of five rabbits in each group, then dried at 60^{oC} for 48 h and grounded for approximate chemical analysis.

At the termination of the experimental period (11 wk of age), blood samples were collected from three animals in each group during slaughtering into sterile tubes. Blood samples were centrifuged immediately at 3500 rpm for 15 min, then blood serum was isolated and kept at $-20^{o}C$ until assayed. Concentrations of serum total proteins, TP and albumin, AL (Valzitidis, 1977), glucose (Kaplan, 1984), total cholesterol, TC (Thomas, 1992), triglycerides, Tri (Fossati, 1982), high density lipoproteins, HDL (Assmann, 1979), low density lipoproteins, LDL (Bauer, 1982), urea (Tabacco *et al.*, 1979) and creatinine (Henry, 1984) were determined. However, globulin (GL) concentration was determined by difference. Activity of aspartate (AST) and alanine (ALT) transaminases were also determined in serum according to Reitman and Frankel (1957). Hormonal concentration of thyroid gland (triiodothyronine, T_3 and tetraiodothyronine, T_4), and testosterone was assayed by radio-inmmuno-assay (RIA). Oxidative status, including total antioxidant capacity (TAC) and malondialdehyde (MDA) was assayed. Immunoglobulins (IgG, IgA and IgM) were determined by ELISA technique.

Data were statistically analyzed by one-way ANOVA design (SPSS 16.0) for Windows (Chicago, IL, USA) to study the effect of treatment on growth performance parameters at each age or age interval throughout the experimental period. However, other data were analyzed only at the end of the experimental period. Completely randomized design was used based on the following model: $Yij = \mu + Ti + eij$, where μ = the overall mean, Ti = treatment (1-3), and eij = residual error. Viability rate and carcass traits percentages were statistically analyzed using Chi-Square test. Differences among treatment means were set by Duncan's multiple range test (Duncan, 1955) at $P<0.05$.

RESULTS AND DISCUSSION

Growth performance:

Growth performance parameters, including live body weight and daily weight gain of rabbits were higher in treated groups (T2 and T3) than in control one (T1), but the significant (P<0.05) differences were obtained only for live body weight at 8 and 11 wk of age and for daily weight gain at 5-8 and 5-11 wk of age intervals. The differences in live body weight and daily weight gain between T2 and T3 were not significant. However, the effect of GA on daily feed intake and feed conversion ratio were not significant at all age intervals, but viability rate during the entire length of the experimental period was higher in T3 than in T1 and T2 (Table 3). These results indicated beneficial effects of dietary supplementation of GA at both levels on growth performance of growing rabbits.

Table (3): Effect of dietary Arabic gum supplementation on growth performance parameters of APRI growing rabbits at different ages.

Item	Control (T1)	Experimental group		P-Value
		T2 (1kg GA/ton diet)	T3 (2 kg GA/ton diet)	
Average live body weight (g)				
At 5 wk (Initial)	726.6±7.77	729.5±7.75	727.2±8.65	0.966
At 8 wk	1324.4±17.6[b]	1378.1±18.01[a]	1388.9±16.76[a]	0.024
At 11 wk (Final)	1994.3±26.6[b]	2076.0±34.07[a]	2097.4±24.54[a]	0.034
Average daily gain (g)				
At 5~8 wk	28.46±0.72[b]	30.89±0.75 [a]	31.51±0.70[a]	0.010
At 8~11wk	31.96±0.73	33.23±0.94	33.74±0.61	0.254
At 5~11 wk	30.13±0.57[b]	32.06±0.77[a]	32.63±0.56[a]	0.020
Average daily feed intake (g)				
At 5~8 wk	101.6±3.26	109.6±2.66	110.6±2.68	0.059
At 8~11wk	159.8±2.47	165.8±3.08	166.2±3.02	0.222
At 5~11 wk	130.7±2.59	137.8±2.69	138.4±2.72	0.088
Feed conversion ratio (g feed/g gain)				
At 5~8 wk	3.57±0.07	3.55±0.08	3.51±0.08	0.836
At 8~11wk	5.00±0.08	4.99±0.09	4.93±0.03	0.503
At 5~11 wk	4.34±0.05	4.27±0.07	4.24±0.05	0.436
Viability rate (%)	93.33	93.33	96.66	-

[a and b] : Means in the same row with different superscripts are significantly different (P<0.05).

Heat stress alleviate lipid oxidant and consequently increases free radical generation which rises ROS production inducing cellular oxidative stress (Hassan *et al.*, 2016). Therefore, impaired growth performance of heat stressed animals in control group (T1) as compared to those in treatment groups (T2 and T3), probably due to increasing ROS generation in T1, which may lead to oxidization and breakdown of biological molecules, inhabitation of some ATP-as activities, and many impairments in the intestinal tissues, growth and feed utilization (Payne and Southern, 2005; Josephine *et al.*, 2008). Improving growth performance of rabbits in treatment groups was mainly explained by insignificant increase in their feed consumption against the negative effect of heat stress on feed intake of rabbits. The observed tendency of increase in feed intake in treatment groups may be attributed to that GA contains complex polysaccharide like rhamnose, arabinose, galactose and glucuronic acid (Wyasu and Okereke, 2012). These contents may improve palatability of diets supplemented with GA, and then feed consumption. In accordance with these findings, Amber *et al.* (2017) reported insignificant effect of dietary GA supplementation on increasing feed intake of growing rabbits. However, Nasir *et al.* (2008) reported unchanged feed intake of mice fed diet treated with GA.

The obtained results indicated significant improvement in weight and gain of rabbits in treatment groups without significant effect on feed intake and FCR. Several authors found that GA supplementation enhances the productive performance of growing rabbits (Tageldin *et al*., 2006; Liu *et al*., 2011; Al-Sagheer *et al.,* 2017). The observed tendency of increasing rabbit viability rate, particularly, with the highest GA level (T3) may be attributed to that GA displays antimicrobial activity and ability to stimulate

the intestinal absorption (Ali *et al.,* 2009), which was in relation with improving antioxidant and immunity systems as affected by GA in our study. In general, natural antioxidants can decrease oxidative damage of intestinal mucosa and enhances rabbit productive performance (Kermauner and Laurenčič, 2008). In this respect, GA has powerful anti-oxidant action (Jaafar *et al.,* 2016) as indicated in our study.

Nutrient digestibility coefficients:

Digestibility coefficients of all nutrients were higher in T2 and T3 than in T1, being the highest in T3, but the differences were not significant, indicating somewhat improvement of nutrient digestion in growing rabbits fed diet supplemented with GA (Table 4).

Table (4): Effect of dietary Gum Arabic supplementation on nutrient digestibility of APRI growing rabbits.

Nutrient (%)	Control (T1)	Experimental group		P -Value
		T2 (1kg GA/ton diet)	T3 (2 kg GA/ton diet)	
Organic matter	69.26±1.02	69.94±0.63	71.12±0.67	0.285
Crude protein	75.09±0.88	75.60±0.57	76.82±0.70	0.265
Crude fiber	31.61±2.13	35.26±2.20	39.01±2.59	0.119
Ether extract	82.08±2.26	82.65±1.26	84.87±1.27	0.480
Nitrogen free extract	73.83±0.18	74.25±0. 21	74.62±0.27	0.085

Carcass traits:

As presented in Table 5, relative weight of foreparts of carcass significantly (P<0.05) decreased, while hind parts significantly (P<0.05) increased in T2 and T3 compared with T1. However, relative weight of the middle parts (loin) and total edible organs was not affected significantly by GA treatment. Along with the positive effect of GA on increasing the hind parts of rabbit carcass, also weight of inedible organs relative to pre-slaughtered weight was significantly (P<0.05) higher in T1 than in T3, in term of relative weight of full digestive tract. These results reflected in significantly (P<0.05) the highest dressing percentage of rabbits in T3 and insignificant increase in dressing percentage of rabbits in T2 as compared to those in T1. Regard to the chemical composition of rabbit meat, GA had insignificant effect on contents of crude protein, ether extract and ash.

Table (5): Effect of dietary Gum Arabic supplementation on carcass traits of APRI growing rabbits.

Item	Control (T1)	Experimental group		P -Value
		T2 (1kg GA/ton diet)	T3 (2 kg GA/ton diet)	
Slaughtered rabbits (n)	5	5	5	-
Carcass part weight (%):				
Fore *	27.99±1.16^{a}	25.66±0.95^{b}	24.20±0.55^{b}	0.040
Loin*	21.58±0.15	21.64±0.08	21.47±0.13	0.641
Hind*	32.78±0.67^{b}	35.15±1.03^{a}	36.81±1.26^{a}	0.048
Total edible organs (%) *	17.65±0.11	17.55±0.07	17.52±0.15	0.218
Inedible organs:				
Blood (%) **	2.33±0.01	2.34±0.01	2.35±0.01	0.390
Pelt distal leg (%) **	19.60±0.39	18.37±0.57	17.42±0.69	0.055
Digestive tract (%) **	18.86±0.32^{a}	17.80±0.48^{ab}	17.02±0.59^{b}	0.042
Other losses (%) **	2.03±0.03	2.13±0.03	2.14±0.05	0.065
Total (%) **	42.82±0.22^{a}	40.64±0.45^{b}	38.93±0.51^{b}	0.042
Dressing (%) **	57.18±0.71^{b}	59.36±1.02^{ab}	61.07±1.25^{a}	0.050
Chemical composition (%):				
Crude protein	18.64±0.02	18.73±0.05	18.68±0.04	0.411
Ether extract	3.48±0.03	3.54±0.02	3.45±0.03	0.168
Ash	1.98±0.01	2.02±0.02	1.97±0.01	0.114

*$^{a, b \text{ and } c}$: Means in the same row with different superscripts are significantly different (P<0.05). * Relative to carcass plus total edible organs weight. ** Relative to pre-slaughtered weight.*

The obtained results are in agreement with several investigators. In this way, Amber *et al*. (2017) found reduction in the digestive tract weight relative to fasting weight of rabbits fed diet supplemented with GA at a level of 1.5%. Also, Dalle Zotte *et al.* (2012) reported that GA level did not provide improvements in carcass traits of growing rabbits. It was observed that increasing LBW of rabbits fed GA supplemented diets in the present study was focused on increasing the relative weight of hind parts of the carcass, reflecting higher dressing percentage of rabbits in T2 and T3 without effects on chemical analysis of rabbit meat. Although feed intake was insignificantly higher in T2 and T3 than in T1, full digestive tract relative to pre-slaughter weight was significantly ($P<0.05$) lower in T2 and T3 than in T1, which may indicate a positive effect of GA on rate of passage within the digestive tract of rabbits. These results indicated that GA had no adverse effects on the carcass traits and meat quality of rabbits.

Liver and kidney functions:

Data of somatic indices indicated significantly the highest hepato- and renal somatic indices in T3 compared with T1 and T2. Concentration of protein fractions, indicated significantly better protein metabolism of rabbits in T2 and T3 than T1.The observed insignificant differences in serum aspartate and alanine transaminases activity and in serum urea concentration as well as significant ($P<0.05$) decrease in serum creatinine concentration in T2 and T3 than in T1 reflected normal liver and kidney function of rabbits in treatment groups (Table 6). The present results indicate no adverse effects of dietary GA supplementation were detected on protein metabolism, feed utilization and enzyme activity leading to functional liver and kidney during the growing period.

Similarly, Amber *et al.* (2017) found significant increase in serum TP, AL and GL concentrations and insignificant differences in AST and ALT activities in rabbits fed GA supplemented diet as compared to their controls. These results may indicate normal metabolism and liver function of rabbits in treatment groups (Khojah, 2017). Moreover, the recorded insignificant differences in urea and decreasing creatinine concentration in serum of rabbits in treatment groups as compared to control may indicate potential and positive effect of dietary GA supplementation on feed utilization and normal kidney function.

Table (6): Effect of dietary Gum Arabic supplementation on liver and kidney functions of APRI growing rabbits.

Item	Control (T1)	Experimental group		P -Value
		T2 (1kg GA/ton diet)	T3 (2 kg GA/ton diet)	
Hepato-somatic index	3.08±0.015^{a}	3.02±0.02^{ab}	2.99±0.03^{b}	0.042
Protein fractions (g/dl):				
Total protein	5.95±0.08^{b}	6.26±0.03^{a}	6.33±0.02^{a}	0.003
Albumin	3.76±0.03^{b}	3.96±0.03^{a}	4.03±0.03^{a}	0.002
globulin	2.19±0.02^{b}	2.30±0.04^{a}	2.30±0.02^{a}	0.007
Transaminases activity (IU/l):				
Aspartate	38.67±1.45	38.33±1.67	37.67±1.85	0.912
Alanine	34.43±0.86	34.00±0.58	33.33±0.34	0.505
Renal-somatic index	0.96±0.02^{a}	0.89±0.03^{ab}	0.83±0.04^{b}	0.050
Protein metabolites (mg/dl):				
Urea	46.33±0.89	44.67±0.88	42.33±1.45	0.108
Creatinine	1.067±0.06^{a}	0.853±0.02^{b}	0.823±0.01^{b}	0.007

$^{a\ and\ b}$: Means in the same row with different superscripts are significantly different ($P<0.05$).

Lipid profile and glucose level:

Dietary GA supplementation in both treatment groups (T2 and T3) significantly ($P<0.05$) reduced serum total cholesterol, triglycerides and low-density lipoproteins concentrations, and increased high-density lipoproteins and glucose concentrations compared with control group (T1) as illustrated in Table 7. These results indicated remarkable effect on lipid profile of growing rabbits. Similar trends were reported in serum of rabbits (Amber *et al.*, 2017) and rats (Eyibo *et al*., 2018). Also, a decrease in blood lipids profile was observed in health and diabetes patients treated with dietary fibers as GA (Lattimer and Haub, 2010). The trend of change in lipid profile of growing rabbits fed GA supplemented diet could be attributed to marked reduction in absorption and/or synthesis of cholesterol in the gastro-intestinal tract (Slavin, 2005). Furthermore, Kishimoto *et al.* (2006) stated that specific bacteria species is most likely

responsible for GA fermentation to propionate, which could limit key enzymes induction of cholesterol metabolism, subsequently decreasing cholesterol level in blood (Illman and Topping, 1988).

Regarding the effect of GA on serum glucose level, Mohamed *et al.* (2015) reported an increase in glucose level in rats treated with GA. Also, plasma glucose was significantly higher for rabbits fed 5% GA diet (Tageldin *et al.,* 2006). This increase in glucose level may be attributed to that GA supplementation significantly reduced urinary glucose excretion, Na+ excretion and urinary volume (Nasir *et al.,* 2012).

Table (7): Effect of dietary Gum Arabic supplementation on serum lipid profile and glucose level in of APRI growing rabbits.

Item	Control (T1)	Experimental group		P - Value
		T2 (1kg GA/ton diet)	T3 (2 kg GA/ton diet)	
Lipid profile (mg/dl):				
Total cholesterol	137.33±1.45[a]	130.00±1.16[b]	126.33±0.88[b]	0.002
Triglycerides	94.00±2.08[a]	86.33±0.88[b]	82.33±1.45[b]	0.005
High-density lipoproteins	59.40±0.31[b]	64.33±1.20[a]	67.00±1.54[a]	0.009
Low-density lipoproteins	42.33±1.45[a]	35.00±1.73[b]	31.67±1.20[b]	0.006
Carbohydrate metabolisms (mg/dl):				
Glucose	105.67±3.48[b]	117.67±1.45[a]	122.00±1.73[a]	0.007

[a and b]: Means in the same row with different superscripts are significantly different (P<0.05).

Oxidative status and immunity response:

Concentration of total antioxidant capacity significantly increased (P<0.05) only in T3 compared with other treatments (T1 and T2), while malondialdehyde concentration significantly (P<0.05) decreased in T2 and T3 compared with T1 (Table 6), reflecting better antioxidant defense system of rabbits in treatment groups (T2 and T3) than in T1 (control group). Also, immunoglobulin (IgG) concentration was significantly (P<0.05) the highest in T3, moderate in T2 and the lowest in T1, while both treatment groups (T2 and T3) showed significantly (P<0.05) higher immunoglobulins (IgM and IgA) concentrations than in T1, reflecting higher immune response of T2 and T3 than in T1 (Table 8).

Table (8): Effect of dietary Gum Arabic supplementation on oxidative and immunity status of APRI growing rabbits.

Item	Control (T1)	Experimental group		P-Value
		T2 (1kg GA/ton diet)	T3 (2 kg GA/ton diet)	
Oxidative status (nmol/l):				
TAC	2.99±0.03[b]	3.02±0.02[b]	3.08±0.015[a]	0.042
Malondialdehyde	7.95±0.08[a]	6.26±0.03[b]	6.33±0.02[b]	0.003
Immunity status (mg/dl):				
IgG	481.67±4.41[c]	514.67±3.71[b]	531.00±2.08[a]	0.001
IgM	150.33±0.88[b]	161.67±1.45[a]	164.00±1.15[a]	0.001
IgA	136.00±2.08[b]	147.67±1.45[a]	152.00±1.73[a]	0.002

[a, b] and [c] : Means in the same row with different superscripts are significantly different (P<0.05).

The beneficial effects of GA on rabbits of T2 and T3 may be attributable to the antioxidant properties of GA as reported by several authors, who indicated this fact in rats (Armogida *et al.,* 2012; Gado and Aldahmash, 2013) as a result of presence of various antioxidant compounds like flavonoids and other polyphenolic compounds (Sadeek, 2018), and antioxidants molecules such as lysine, tyrosine and histidine amino acid residues (Park *et al.,* 2005). In addition, rats administrated with GA significantly increased enzymatic antioxidants activity such as SOD, catalase, GSH and GPx (Sadeek, 2018) and increased TAC level in human (Kaddam *et al.,* 2017). The GA may directly combine with free radicals, leading to their inactivation by decrease free radicals in the cells (Priscilla and Prince, 2009). According

to the obtained results and those previously reported, GA is considered as a good anti-oxidant for improving antioxidant defense system (Kassem, 2015).

The present results proved the antioxidant properties of GA as found also on immunity of growing rabbits. Such results proved a negative relationship between TAC and MDA, while a positive relationship was observed between antioxidant and immunity systems. Also, GA supplementation resulted in significant improvement in immunoglobulins concentration (IgG, IgM and IgA) in rabbits. Similar findings were obtained by kamal *et al*. (2018) in human and by Ali *et al*. (2013) in mice. Also, Ushida *et al.* (2011) and Ali *et al.* (2013) found an increase of anti-inflammatory cytokine IL10 and a decrease in tumor necrosis factor α expression in the adipose tissues of GA treated mice. The GA has a particularly strong effect on formation of IL-10 and IL-6, which regulate the immune response (Xuan *et al.*, 2010). Moreover, GA seemed to block the function of hepatic macrophage (Gamal El-din *et al.*, 2003). Such findings indicated that GA has advantageous on animal immunity as proved on rabbits in our study.

Thyroid hormones (T_3 and T_4) and testosterone level:

Concentration of serum triiodothyronine was significantly (P<0.05) higher in T3 than in T1 and T2, while concentrations of serum tetraiodothyronine and testosterone significantly (P<0.05) increased in T2 and T3 than in T1 (Table 9).

Table (9): Effect of dietary Gum Arabic supplementation on serum concentration of thyroid and androgen hormones of APRI growing rabbits.

Item	Control (T1)	Experimental group		P -Value
		T2 (1kg GA/ton diet)	T3 (2 kg GA/ton diet)	
Thyroid hormones (ng/ml):				
Triiodothyronine	1.11±0.06^{b}	1.23±0.05^{a}	1.47±0.04^{a}	0.008
Tetraiodothyronine	2.72±0.02^{c}	2.85±0.03^{b}	3.95±0.05^{a}	0.001
Androgen hormone (ng/ml):				
Testosterone	2.350±0.03^{c}	2.817±0.06^{b}	3.00±.01^{a}	0.001

$^{a, b}$ and ^{c}: Means in the same row with different superscripts are significantly different (P<0.05).

Beside different impacts of GA on performance of rabbits, our study indicated positively higher concentration of serum T_3, which significantly decreases after submission to heat stress (Khalil *et al.*, 2013). The observed increase in testosterone of rabbits treated with GA in our study was proved in rats by Jaafar *et al*. (2016), who concluded that GA administration reduced lipid peroxidation, improved the activities of testicular antioxidant enzymes and decreased damage of rat testes. Also, Fuhrman *et al.* (2000) showed that natural antioxidant may target cholesteryl ester hydrolase, which produce free cholesterol from cholesteryl esters for testosterone synthesis.

CONCLUSION

Conclusively, dietary supplementation with Gum Arabic (2 kg/ton diet) can enhance productive performance, lipid profile, immune response and antioxidant defense system of growing rabbits under Egyptian summer conditions without adversely effects on liver and kidney function. Gum Arabic can safely be used in diets as a natural antioxidant and metabolic agent in field of rabbit production.

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الاداء الانتاجى ، صفات الذبيحة ، مستوى الدهون ، حالة مضادات الاكسدة والمناعة للأرانب النامية المعاملة بالصمغ العربى تحت ظروف الصيف فى مصر

ابراهيم طلعت الرطل [1] ، رحاب فوزى صديق عبد الفتاح اسماعيل[2] و سارة فكرى فودة [3]

[1] قسم انتاج الدواجن- كلية الزراعة جامعة دمياط - مصر.

[2] قسم انتاج الحيوان – كلية الزراعة جامعة المنصورة- المنصورة- مصر

[3] قسم انتاج الدواجن- كلية الزراعة جامعة المنصورة- المنصورة - مصر

تهدف هذه الدراسة الى تقييم تأثير الصمغ العربى كمضاد للأكسدة فى علائق الارانب النامية على خصائص النمو والذبيحة، معاملات الهضم، وظائف الكلى والكبد، نشاط مضادات الاكسدة، الاستجابة المناعية وهرمونات الغدة الدرقية والتستوستيرون تحت ظروف الجو الحار فى مصر. استخدمت فى هذه الدراسة 90 من ذكور الارانب النامية (ابرى) مقسمة الى 3 مجموعات متشابهة. غذيت أرانب المجموعة الاولى على عليقة مقارنة (كنترول) ، بينما غذيت ارانب المجموعة الثانية والثالثة على نفس العليقة مضاف اليها 1و2 كجم صمغ عربى/ طن عليقة، على التوالى من عمر 5اسابيع حتى عمر 11 أسبوع. تم تقدير الوزن الحى، معدل استهلاك العلف اليومى، معدل الزيادة اليومية ومعامل التحويل الغذائى خلال فترات النمو المختلفة. وقد اوضحت النتائج ان: اضافة الصمغ العربى ادى الى زيادة معنوية فى معدل النمو(الوزن الحى- الزيادة فى الوزن اليومى)، خصائص الذبيحة (اوزان الاجزاء الخلفية ومعدل التصافى)، تركيزات البروتين الكلى، الالبيومين، الجلوبيولين، الليبوبروتينات مرتفعة الكثافة، الجلوكوز، نشاط مضادات الاكسدة الكلية ، الاستجابة المناعية (تركيز الجلوبيولينات المناعية)، هرمونات الغدة الدرقية والتستوستيرون (هرمون الجنس الذكرى). لم يلاحظ وجود تأثير معنوى لاضافة الصمغ العربى على معدل استهلاك العلف اليومى، معامل التحويل الغذائى، معاملات الهضم ، أوزان الاجزاء القابلة للأكل للذبيحة، التركيب الكيماوى للحم ونشاط انزيمات الكبد وتركيز اليوريا. لوحظ انخفاض معنوى فى الوزن النسبى لأجزاء الذبيحة الخلفية، وزن القناة الهضمية، تركيزات الكوليسترول، الجليسريدات الثلاثية، الليبوبروتينات منخفضة الكثافة، الكرياتينين والمالونداياالدهيد عند اضافة الصمغ العربى لعلائق الارانب النامية. وقد اظهرت المعاملة الثالثة أحسن النتائج.

وتخلص الدراسة الى أن اضافة الصمغ العربى كمضاد للأكسدة الى علائق الارانب النامية (2كجم/طن عليقة) يمكن ان يحسن من معدل الأداء الانتاجى، مستوى الدهون، الاستجابة المناعية ونشاط مضادات الاكسدة تحت ظروف الصيف فى مصر، دون حدوث اى تأثير سلبى على وظائف الكلى والكبد.