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Growth Performance, Carcass Characteristics And Blood Biochemical Of Male APRI Growing Rabbits Supplemented With Onion Peel Extract During Summer season in Egypt

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ABSTRACT

A feeding trial of 8 weeks was performed to evaluate effects of dietary onion peel extract (OPE) supplementation on the growth performance, carcass traits and blood biochemical indicators of male APRI grwoing rabbits during Egyptian summer environments. Thirty-six weaned male rabbits (646 ± 15.39 g) were randomly allocated to four trial groups (9 rabbits in each group) as a completely randomized design. The first group was fed a control diet without supplementation, while the other three diets supplemented groups with OPE at 200, 350, and 500 mg/kg diet.

The findings indicated that dietary supplementation with OPE at levels of 200 or 350 mg/kg diet significantly (P<0.001) enhanced live body weight at 9 and 13 weeks of age compared to the control group. OPE supplementation led to improvements in growth performance indicators including body weight gain, relative growth rate, and feed conversion ratio, whereas feed intake and carcass traits showed no significant changes. The serum cholesterol profile showed favorable changes, with a reduction in total cholesterol, LDL-C, and VLDL-C levels (P≤0.01), and a slight increase in HDL-C (P=0.052), while triglyceride levels remained unchanged. OPE supplementation at levels of 200 or 350 mg/kg resulted in an increase in serum total

protein, with the 200 mg/kg diet level significantly enhanced serum albumin (P<0.05) and serum globulin (P<0.01) levels. The antioxidant status was enhanced, evidenced by decreasing malondialdehyde levels (P<0.01) and elevating concentrations of catalase and glutathione, especially at levels of 200 and 500 mg/kg diet. Immunological responses indicated a significant increase in IgM (P<0.05) in the 200 mg/kg group, elevated IgG levels (P<0.05) at 350 mg/kg diet, and enhanced lysozyme activity (P<0.01) at both 200 and 350 mg/kg when compared to control group.

Conclusively, from these results it could be concluded that dietary supplements with OPE at levels 200 and 350 mg/kg diet enhanced growth performance, blood cholesterol levels, immune response, and antioxidant activity in fattening ABRI rabbits subjected to heat stress in Egypt.

Keywords: Onion Peel Extract, Growth Performance, Carcass Characteristics, Heat stress, APRI Rabbits.

INTRODUCTION

Heat stress poses a significant challenge in animal husbandry, especially in hot climates, adversely affecting growth performance, carcass characteristics, meat quality, blood variables, and immunity in growing rabbits (Liang *et al.*, 2022; Oladimeji *et al.*, 2022; Ebeid *et al.*, 2023). Although rabbits are homeothermic and capable of maintaining a stable body temperature, their thermoregulatory system is less efficient due to poorly functioning sweat glands and a thick insulating fur layer (Ebeid *et al*., 2023). As a result, rabbits exhibit a higher susceptibility to heat stress than other species of livestock. (Oladimeji *et al.*, 2022). The typical body temperature of rabbits is between 38.5 and 39.5°C, with an ideal ambient temperature of 15 to 25°C and humidity levels of 55 to 60%. Heat stress commences when temperatures are above 30°C, and at levels over 35°C rabbits encounter difficulties in thermoregulation, leading to heat failure (Liang *et al*., 2022).

Various dietary strategies have been explored to mitigate the effects of heat stress in rabbits, aiming to improve growth performance, immune response, and overall resilience under these challenging environmental conditions (Oladimeji *et al.*, 2022). These interventions often include supplementation with antioxidants, probiotics, and minerals that support thermal tolerance and enhance physiological responses during heat exposure (Ebeid *et al*., 2023).

Recently, the incorporation of plant extracts and essential oils as growth enhancers in rabbit diets gained interest. Kone *et al.* (2016) found that plant extracts and essential oils can be incorporated into rabbit diets without adversely affecting performance or meat quality. Hassan *et al.* (2021) similarly reported that the incorporation of tomato pomace and orange peel extracts, rich in ascorbic acid, enhanced economic efficiency and growth performance; and diminished plasma concentrations of cholesterol and low-density lipoprotein cholesterol in rabbits. Elazab *et al.* (2022) indicated that ginger and rosemary essential oils improved rabbit performance, reduced meat cholesterol, and elevated plasma triglycerides and cholesterol, while meat composition remained unaltered. Mohamed *et al.* (2023) established that dietary supplementation with extracts of thyme, garlic, turmeric, clove, and cinnamon (200 mg/kg diet) enhanced nutrient digestibility, growth performance, immunity, and antioxidant activity in growing rabbits, resulting in superior meat production.

Onion (*Allium cepa* L.) is known for its pharmacologically active compounds, such as flavonoids, organosulfur compounds, and phenolic compounds, which have shown antibacterial, antioxidant, and antihypertensive effects in both humans and animals (Osipova *et al.*, 2021). The potential of agricultural by-products as feed additives in animal nutrition has garnered significant interest due to their ability to enhance growth performance and improve animal health. Plant extracts, rich in bioactive compounds, are commonly obtained through solvents like water, ethanol, and methanol (Alcázar-Alay *et al*., 2017; Kumar *et al*., 2022). The ethanolic extract of yellow onion skin, for example, contains significant amounts of gallic acid equivalents and quercetin equivalents, both known for their antioxidant properties (Lee *et al*., 2014).

The APRI breed rabbit which developed by crossing Egyptian Baladi Red bucks with Spanish V-Line does at the Animal Production Research Institute, Agricultural Research Center, Ministry of Agriculture, Egypt, is a newly developed meat rabbit line (Youssef *et al*., 2008; Abou Khadiga *et al*., 2010).

Therefore, this research aimed to evaluate the impact of onion peel extract-enriched diets on carcass traits, growth performance, and blood biochemical responses of growing APRI rabbits under the challenging conditions of the Egyptian summer. The findings from this study could contribute to developing economical and eco-friendly feeding strategies for rabbit farming in hot climates.

MATERIALS AND METHODS

The present study was conducted at the Rabbitry of the Animal Production Department, Faculty of Agriculture, Zagazig University, during the summer season, specifically from June to July 2022.

Preparation of onion peel extract:

The dietary onion peel extract (OPE) was prepared according to the method described by Park *et al.* (2009). The onion extraction technique was made in the Agricultural Chemistry Department, Faculty of Agriculture, Zagazig University, Egypt.

The fresh onions bulbs were purchased from the local Egyptian market. The leaves of fresh onions and their outer skins were carefully separated. One hundred grams of onion skins were minced and homogenized in 250 mL of 70% methanol. The homogenate was stirred for two hours and subsequently filtered using Whatman No. 2 filter papers. Methanol was extracted from the sample using a Büchi-water bath-B-480 evaporator under vacuum at 45°C, subsequently undergoing lyophilization in a freeze dryer.

Experimental rabbits, diets and management:

Thirty-six weaned male APRI kits (initial average weight 646 ± 15.39 g) at five weeks of age were randomly assigned to four experimental groups (9 rabbits in each) as a completely randomized design. Each experimental group implicated 9 replicates, one rabbit per each replicate. The rabbits were housed in an open-sided, well-ventilated rabbitry, equipped with individual galvanized-wire cages, feeders, and automatic nipple drinkers. Each rabbit kit served as an experimental unit. The cage dimensions were 55 cm in length, 50 cm in width, and 40 cm in height. Prior to the trial, the rabbitry and all its equipment (cages, feeders, and drinkers) were thoroughly disinfected, and all necessary managerial practices and biosecurity measures were strictly followed.

A basal diet, formulated to meet the essential nutritional requirements for growing rabbits as per the National Research Council (NRC, 1977), was used. The basal diet was supplemented with onion peel extract (OPE) at four levels: 0.0, 200, 350, and 500 mg/kg diet.

Thus, four experimental diets were prepared for the duration of 5-13 weeks (to span the designed 8 weeks of testing period). The OPE was added to the diets before pelleting. Feed (in pelleted form) and fresh water were provided *ad libitum* to all experimental groups. All the experimental groups were managed in the same way. The ingredient composition and calculated nutritional analysis of the basal (control) diet are presented in Table 1.

Table 1: Composition and calculated analysis of the basal diet used in this study

Ingredients:	%	Nutrients*	Content
Alfalfa hay	30	Digestible energy, kcal/kg	2503
Wheat bran	27	Crude protein (%)	16.08
Yellow corn	16	Ether extract (%)	2.75
Barley grains	12	Crude fiber (%)	12.99
Soybean meal (44% CP)	10	Ca (%)	0.79
Molasses	3.0	Total P (%)	0.63
Ground limestone	0.5	Lysine (%)	0.72
Dicalcium phosphate	0.4	Methionine (%)	0.31
Common salt	0.5	Methionine + Cystine (%)	0.62
Vit. & Min. Premix[§]	0.5		
DL-Methionine	0.1		
Total	**100**		

[§]Each kilogram contains: Vit. A, 12,000 IU, Vit. D_3, 2,200 IU, Vit. E, 10.0 mg, Vit. K, 2.0 mg, Vit. B_1, 4.0 mg, Vit. B_2, 1.5 mg, Pantothenic acid, 6.3 mg, Vit. B_6, 1.7 mg, Vit. B_{12}, 0.03 mg, Biotin, 3.3 mg, Folic acid, 0.83 mg, Choline chloride, 200 mg, Zn, 11.79 mg, Mn, 5.00 mg, Fe, 12.5 mg, I, 0.33 mg, Se, 0.65 mg and Mg 66.79 mg.
*Calculated analysis (As fed basis: NRC, 1977).

Temperature-humidity index (THI):

THI value was determined weekly throughout the experimental period using the proposed equation by Marai *et al.* (2001) as follows: THI = Tem - [(0.31 - 0.31 × RH) (T - 14.4)], where RH represents relative humidity as a fraction (percentage/100), and Tem denotes the ambient temperature in Celsius. The calculated THI values are categorized into four levels of thermal stress: THI < 27.8: Thermal comfort zone; 27.8 ≤ THI < 28.9: Mild to moderate heat stress; 28.9 ≤ THI < 30.0: Severe heat stress; THI > 30.0: Very severe heat stress.

Growth performance of rabbits:

Live body weight (LBW) and daily feed intake (FI) of individual kits were estimated weekly before feeding at the start of the study (5 weeks old), 9 and 13 weeks of age (the end of the study).

Thus, daily weight gain (DWG) and feed conversion ratio (FCR) were determined weekly throughout periods 5-9,9-13 and 5-13 weeks os age (the whole experimental period). DWG were computed as follows:

[Final LBW (g) minus Initial LBW (g)] / No. of days, and
FCR was estimated as DFI (g) / DWG (g).

Also, the relative growth rate (RGR: %) was calculated as follows:

100 [BWG] divided by 0.5 multiplied by the sum of initial LBW plus final LBW, during of same period studies .

Carcass characteristics of rabbits:

At the end of the experiment (13 weeks of age), three rabbits from each treatment group were randomly selected and euthanized following a 12-hour fasting period. Immediately following the recording of the preslaughter live body weight of rabbits, they were meticulously sacrificed, skinned, and eviscerated. The weights of the hot carcass, including the head (carcass yield: CY), liver, heart, kidneys), and lungs were measured.

Blood biochemical parameters:

During slaughter, three blood samples in each treatment group were taken in non-heparinized test tubes. After blood clotting, they were centrifuged for separating blood serum.

The blood sera were frozen at – 20°C until later analysis. The blood serum concentrations of total protein (TP) according to Doumas *et al*. (1981), albumin (ALB) according to Doumas *et al*. (1971), total cholesterol (TC) according to Allain *et al*. (1974), triglycerides (TRI) according to Fossati and Prencipe (1982), high density lipoprotein-cholesterol (HDL-C) according to Sawle *et al*. (2002), low density lipoprotein-cholesterol (LDL-C) according to Pisani *et al*. (1995), malondialdehyde (MDA) according to Banjare *et al*. (2017), creatinine (CRE) and urea-N (UN) by methods of Lyman (1986), immunoglobulins (IgG and IgM) by methods of Yel *et al.* (2015), glutathione (GSH) by methods of Rahman *et al*., (2006), thyroxin (T4) by methods of Britton *et al*., (1975), cortisol (COR) by methods of Turpeinen and Hämäläinen (2013), Na and K (Hübl *et al.*, 1994), and activities of lysozyme (LYS) by methods of Brouer *et al*., (1984) catalase (CAT) by methods of Goth, (1991), alanine aminotransferase (ALT) and aspartate aminotransferase (AST) as described by Reitman and Frankel (1957) were determined using commercial kits. The serum level of very low density lipoprotein-cholesterol (VLDL-C) was calculated as the concentration of TRI multiplied by 0.20 (Friedewald *et al*., 1972). Serum globulin (GLO) level was estimated by the difference between serum TP and serum ALB, and thus, albumin: globulin (A:G) ratio was computed.

Statistical analysis

The data were statistically processed by a one-way analysis of variance according to Snedecor and chocoran (1982) using SAS Program (SAS, 2006).

Significant differences among variables were identified by the use of Duncan's multiple range test (Duncan, 1955), with $P \leq 0.05$ considered to be significant. To exclude the effect of pre-slaughter weight on carcass parameters, an analysis of covariance (ANCOVA) was applied to the data of hot carcass and organ weights.

RESULTS AND DISCUSSION

Temperature-humidity index (THI):

Table 2 presents the temperature-humidity index (THI) recorded during an eight-week experimental period. The mean values of air temperature and relative humidity during the hot climate were 32.95 ◦C and 56.68%, respectively. The calculated value of THI was 30.46. Weekly calculated THI values exceeding 29.00 demonstrate that the experimental animals experienced very severe heat stress throughout the entire experimental period.

Table 2. The temperature-humidity index during the experimental periods.

Experimental	Temperature, °C	Humidity percent	*THI
Week 1	31.63±0.375	56.50±0.645	29.30±0.352
Week 2	32.25±0.250	55.50±0.645	29.79±0.209
Week 3	32.50±0.289	55.75±0.750	30.02±0.260
Week 4	33.25±0.250	55.25±0.750	30.63±0.194
Week 5	33.50±0.289	56.00±1.354	30.89±0.207
Week 6	33.50±0.289	57.50±0.957	30.98±0.240
Week 7	33.50±0.289	58.75±1.601	31.06±0.226
Week 8	33.50±0.289	58.25±0.250	31.03±0.217
Overall mean	32.95±0.256	56.68±0.467	30.46±0.236

*THI was calculated according to the equation of Marai *et al*. (2001) as: THI = Tem - [(0.31 - 0.31 × RH) (T - 14.4)], where RH = relative humidity as a fraction (percentage/100), and Tem = the ambient temperature in Celsius.

The temperature starts at 31.63°C during the first week and increases to 33.50°C by the fifth week, remaining steady at 33.50°C from the fifth to the eighth week. Also, the humidity ranges between 55.25% and 58.75%. Initially, it decreases slightly from 56.50% to 55.25% from the first to the fourth week, and then increases to 58.75% in the seventh week, showing a slight decrease to 58.25% in the eighth week. The temperature-humidity index starts at 29.30 in the first week and gradually rises to 31.03 by the eighth week. This indicates an

increasing level of discomfort associated with the combined effects of temperature and humidity over time.

The rise in temperature over the weeks suggests that the experimental period likely covers a warm season or that the environment in which the experiment was conducted is progressively heating up. A steady temperature of 33.50°C from the fifth to the eighth week indicates a plateau, likely representing the peak temperature during the period. The THI values represent the combined effects of temperature and humidity on perceived comfort levels. As the THI values increases from 29.30 to 31.03, it indicates a growing level of discomfort. This is significant in understanding how environmental conditions impact living organisms or systems being studied during the experiment. According to Gaughan *et al*. (2008), a THI above 30 can start causing heat stress in livestock, while values above 32 are considered critical. The THI values in this experiment suggest that by the seventh and eighth weeks, the conditions are approaching or exceeding these critical levels, potentially affecting the health or performance of the subjects under study. The increase in temperature and humidity, along with the rising THI, highlights the importance of monitoring and managing environmental factors to ensure the well-being of the subjects involved in the study.

Growth performance and feed efficiency:

Table 3 shows the growth performance results of APRI rabbits fed diets supplemented with OPE during the Egyptian summer, covering the period from 5 to 13 weeks of age. At 9 weeks, rabbits receiving 200 mg OPE exhibited significantly greater weights than the other groups ($P < 0.001$). The trend persisted at 13 weeks, with the 200 mg OPE group exhibiting the highest LBW. From 5 to 9 weeks, the 200 mg OPE group demonstrated the highest daily body weight gain ($P<0.001$). From 5 to 13 weeks, the 200 mg/kg OPE group consistently demonstrated superior daily BWG ($P<0.001$). The RGR between 9 and 13 weeks did not exhibit significant differences. When considering the entire period (5 to 13 weeks), the 200 mg/kg OPE group had the highest RGR ($P<0.037$).

There were no significant differences in daily FI across the groups during any of the periods measured. From 5 to 9 weeks, the 200 mg/kg OPE group had a significantly better FCR compared to the control group ($P=0.036$). Although the FCR from 9 to 13 weeks did not show significant differences, the trend observed in the initial period was crucial. For the entire duration (5 to 13 weeks), the 200 mg OPE group showed a significantly better FCR ($P=0.016$).

Table 3: Growth performance and feed efficiency of APRI rabbit in response to feeding onion peel extract (OPE) enriched diets under Egyptian summer conditions from 5 to 13 weeks of age

Measurements:	Dietary OPE (mg/kg)				SEM	*P* Value
	(Control)	200	350	500		
LBW (g) at:						
5 weeks	621	650	654	660	15.39	0.861
9 weeks	1025^{c}	1270^{a}	1132^{b}	1115^{bc}	36.18	<0.001
13 weeks	1463^{c}	1835^{a}	1645^{b}	1540^{c}	25.64	<0.001
Daily BWG (g):						
5-9 weeks	14.43^{b}	22.14^{a}	17.07^{b}	16.25^{b}	0.81	0.001
9-13 weeks	15.64	20.18	18.32	15.18	1.26	0.060
5-13 weeks	15.04^{c}	21.16^{a}	17.70^{b}	15.71^{bc}	1.11	<0.001
RGR (%):						
5-9 weeks	49.09^{b}	64.58^{a}	53.53^{b}	51.27^{b}	2.28	0.045
9-13 weeks	35.21	36.39	36.95	32.02	3.06	0.651
5-13 weeks	80.81^{b}	95.37^{a}	86.21^{ab}	80.00^{b}	2.27	0.037
Daily FI (g):						
5-9 weeks	82.39	88.86	86.73	88.42	1.30	0.411
9-13 weeks	106.01	108.1	105.65	103.96	1.34	0.253
5-13 weeks	94.66	98.83	96.53	96.47	0.52	0.509
FCR (g feed: g gain):						
5-9 weeks	5.71^{a}	4.01^{b}	5.08^{ab}	5.44^{ab}	0.42	0.036
9-13 weeks	6.78	5.36	5.77	6.85	0.86	0.452
5-13 weeks	6.30^{a}	4.67^{b}	5.45^{a}	6.14^{a}	0.54	0.016

a-c: Means in the same row having different superscripts differ significantly (P≤0.05). SEM: Standard error of the means. LBW: Live body weight, BWG: Body weight gain, RGR: Relative growth rate, FI: Feed intake and FCR: Feed conversion ratio.

Our findings align with those of Abd El-Hady *et al*. (2013), who indicated that dietary supplementation with Digestarom®—a blend of natural herbs and spices enhanced with specific extracts and essential oils—resulted in notable enhancements in LBW, BWG, FCR, and nutrient digestibility in growing rabbits. Consistent with our findings, Zeweil *et al*. (2016) administered diets containing dried onion (400 or 800 mg/kg diet) to growing rabbits from 5 to 15 weeks of age, resulting in a significant increase in final LBW compared to the control group.

Similarly, Omar *et al*. (2020) observed that the growth performance (LBW, daily WG, and daily FI) of broiler chicks improved with phenolic-rich onion extract compared to the control group; however, FCR remained

unaffected. Furthermore, Abdalkarem and Mohamed (2022) noted a substantial favorable impact of administering red OPE-enriched meals (3.0, 6.0, or 9.0%) on the growth performance of broiler chicks subjected to heat stress. Conversely, Malematja *et al.* (2023) discovered that the incorporation of onion extracts (at concentrations of 5.0-25.0 g/kg dry matter) in broiler chicken diets did not have beneficial impacts on their growth performance (BWG, FI, and FCR) from one to 42 days of age. The inconsistent responses of the experimental animals to different dietary plant extracts are mainly attributed to their variability in bioactive compounds, animal species (rabbits, poultry, pigs, or rats), the used part of the plant, method of extraction, the added dose, diet composition, the method of administration (orally, via drinking water, or in feed) and the period of study (Škerget *et al*., 2009; Zhao *et al.*, 2021; Sagar *et al.*, 2022).

The growth-promoting effect of OPE in rabbits, reported in this study, could be induced by enhancing the activity of digestive enzymes leading to improving the digestibility of nutrients and reducing the pathogenic microorganisms that enhance gut function and immunity. In this regard, Osipova *et al.* (2021) stated that the onion contains many pharmacologically active components like flavonoids, organosulfur compounds, and phenolic compounds, which have antibacterial, antioxidant, and antihypertensive actions.

Carcass characteristics:

Table 4 presents the carcass characteristics of 13-week-old APRI rabbits fed OPE-enriched diets, under Egyptian summer conditions. Pre-slaughter weight was significantly affected by OPE levels (P=0.003), which in turn significantly influenced hot carcass weight and lung weight. However, an analysis of covariance (ANCOVA) of carcass components, adjusting for pre-slaughter live body weight, revealed that hot carcass weight, carcass yield, and the weights of the liver, and lungs were not significantly influenced by dietary OPE levels.

Similarly to our findings, Adeyemi *et al.* (2022) indicated that the dietary supplementation of onion skin had no impact on carcass weight, dressing %, or the relative weights of carcass cuts and internal organs in New Zealand White (NZW) rabbits.

The findings of this study concur with those of Omar *et al.* (2020), who determined that the carcass yield and giblets (liver, heart, and gizzard) of broiler chickens were unaffected by diets supplemented with phenolic-rich onion extract from 4 to 35 days of age. The results we obtained align with those of Malematja *et al.* (2023), indicating that varying inclusion levels of onion extracts (5.0 to 25 g/kg dry matter) in the diets of broiler chickens from day-old to six weeks of age did not influence the absolute weights of carcass, breast meat, thigh, drumstick, and wings at the time of slaughter.

Table 4: Carcass characteristics of APRI rabbit in response to feeding OPE-enriched diets under Egyptian summer conditions

Measurements:	Dietary OPE (mg/kg)				SEM	*P* Value	ANCOVA
	0 (Control)	200	350	500			
Preslaughter LBW (g)	1603[b]	1823[a]	1603[b]	1491[b]	40.45	0.003	....
Hot carcass weight (g)	972[ab]	1063[a]	937[b]	897[b]	22.36	0.020	0.737
Carcass yield (%)	60.63	58.31	58.47	60.13	0.62	0.499	0.728
Liver weight (g)	46.78	50.20	44.86	46.70	1.89	0.838	0.756
Kidneys weight (g)	12.55	10.86	12.44	14.13	0.76	0.567	0.956
Heart weight (g)	12.67	11.34	14.63	11.44	0.78	0.455	0.375
Lungs weight (g)	5.50[b]	8.32[a]	4.95[b]	4.89[b]	0.49	0.010	0.336

a-b: Means in the same row having different superscripts differ significantly (P≤0.05).
SEM: Standard error of the means. LBW: Live body weight, ANCOVA: Analysis of covariance: To exclude the pre-slaughter weight effect, the data of hot carcass and organs weights were statistically analyzed by covariance analysis. Hence the measurements could be compared between groups on carcasses of the same weight.

Also, in an earlier study, An *et al.* (2015) detected no beneficial effect from feeding onion extract-supplemented diets (0.3 or 0.5%) for 5 weeks on the relative weights of the CY and edible parts in broiler chickens.

Blood Biochemical Parameters:

The Table 5 presented the blood serum biochemical parameters of 13-week-old APRI rabbit bucks fed with OPE-enriched diets under Egyptian summer conditions. No significant difference in TRI concentrations was observed across the experimental groups. However, significantly lower levels of TC, VLDL-C, and LDL-C were found in the 200, 350, and 500 mg OPE groups compared to the control. In contrast, HDL-C levels were minimally elevated in the 350 and 500 mg/kg groups (P= 0.052).

This hypocholesterolemic effect aligns with previous studies that reported a cholesterol-lowering effect of onion skin extract (Škerget *et al*., 2009; Duan *et al.*, 2015). Specifically, the reduction in serum TC, VLDL-C, and LDL-C in the OPE-treated groups mirrors findings by Abdalkarem and Mohamed (2022) in broiler chickens under heat stress. Four potential mechanisms may explain this effect, including inhibition of cholesterol biosynthesis, promotion of cholesterol conversion to bile acids, increased excretion, or reduced intestinal absorption.

Table 5: Blood biochemical parameters of APRI rabbit bucks in response to feeding OPE-enriched diets under Egyptian summer conditions

Parameters:	Dietary OPE (mg/kg)				SEM	*P* Value
	0.00	200	350	500		
Lipid Profile (mg/dL):						
TRI	61.01	67.34	65.72	46.70	3.861	0.224
TC	156.63^{a}	93.31^{b}	99.66^{b}	106.68^{b}	7.413	0.001
HDL-C	45.71	51.54	53.41	54.38	1.277	0.052
LDL-C	96.20^{a}	29.56^{b}	37.07^{b}	43.64^{b}	7.458	<0.001
VLDL-C	14.72^{a}	12.21^{ab}	9.18^{b}	8.69^{b}	0.808	0.009
Protein Profile:						
TP, g/dL	5.00^{b}	7.20^{a}	6.66^{a}	5.55^{b}	0.257	<0.001
ALB, g/dL	2.78^{b}	3.69^{a}	3.38^{ab}	2.92^{b}	0.134	0.039
GLO, g/dL	2.22^{c}	3.51^{a}	3.29^{ab}	2.64^{bc}	0.165	0.005
A: G ratio	1.25	1.15	1.03	1.11	0.058	0.639
UN, mg/dL	35.07	40.07	37.22	35.13	1.141	0.394
CRE, mg/dL	0.50	0.42	0.44	0.42	0.014	0.149
Antioxidant Indices:						
GSH, ng/mL	86.33^{c}	390.00^{a}	151.33^{bc}	244.67^{b}	33.90	0.030
CAT, ng/mL	1.70^{c}	2.03^{c}	3.52^{b}	4.84^{a}	0.353	0.011
MDA, nmol/mL	5.47^{a}	1.23^{b}	2.19^{b}	2.05^{b}	0.580	0.001
Immunological Indices:						
IgG, ng/mL	387.67^{b}	383.00^{b}	479.33^{a}	398.33^{b}	14.139	0.030
IgM, ng/mL	253.33^{b}	429.33^{a}	330.33^{ab}	258.00^{b}	23.881	0.011
LYS, ng/mL	2.54^{b}	4.06^{a}	2.40^{b}	3.46^{a}	0.206	0.001
Stress Hormones:						
COR, ng/mL	38.67	62.67	48.67	57.33	3.454	0.052
T4, µg/dL	2.29^{b}	5.45^{a}	4.38^{a}	5.84^{a}	0.428	0.002
***Liver Enzymes*:**						
ALT, U/L	57.63	54.12	56.17	56.58	2.113	0.959
AST, U/L	56.92	52.64	56.29	54.72	1.349	0.725
Electrolytes:						
Na, mmol/L	141.00	137.33	138.67	143.67	1.014	0.117
P, mmol/L	4.18	4.44	4.42	3.92	0.106	0.287

$^{a-c}$: Means in the same row having different superscripts differ significantly (P≤0.05).
SEM: Standard error of the means. TRI: Triglycerides, TC: Total cholesterol, HDL-C: High density lipoprotein-cholesterol, LDL-C: low density lipoprotein-cholesterol, VLDL-C: Very low density lipoprotein-cholesterol, TP: Total protein, ALB: Albumin, GLO: Globulin, A:G ratio: Albumin: Globulin ratio, UN: Urea nitrogen, CRE: Creatinine, GSH: Glutathione, CAT: Catalase, MDA: Malondialdehyde, IgG and IgM: Immunoglobulins G and M, LYS: Lysozyme, COR: Cortisol, T4: Thyroxin, ALT: Alanine aminotransferase and AST: Aspartate aminotransferase.

Significantly higher levels of TP, ALB, and GLO were observed in the 200 and 350 mg/kg groups compared to the control (P = 0.001 and 0.039; Table 5). These changes suggest that OPE supplementation may enhance protein synthesis or improve nutrient absorption, which has been supported

by similar findings in other studies (Ghalehkandi *et al.,* 2012). However, UN and CRE concentrations did not significantly differ across the groups, indicating no renal impact of OPE supplementation.

The GSH level in the 200 mg/kg treatment was significantly elevated compared to the control (P=0.03; Table 5). Furthermore, CAT activity was markedly increased in the 350 mg/kg and 500 mg/kg groups (P = 0.011), although MDA levels were significantly decreased in the 200 mg/kg, 350 mg/kg, and 500 mg/kg groups (P<0.001).

These antioxidant improvements could be due to the high phenolic and flavonoid content of onion skin, which are known for their antioxidant properties (Škerget *et al*., 2009; Duan *et al*., 2015). The reduction in MDA aligns with previous studies where onion extract reduced oxidative stress markers in animals (Dosoky *et al.,* 2021; Li *et al*., 2020). IgG levels were considerably increased in the 350 mg/kg group relative to the control (P=0.03), whereas IgM levels were significantly increased in both the 200 mg/kg and 350 mg/kg groups (P<0.011). Moreover, lysozyme activity was markedly elevated in the 200 and 500 mg/kg groups (P<0.001). These results suggest that OPE supplementation may enhance immune function, a finding consistent with studies on the immunomodulatory effects of onion extract in livestock (Zeweil *et al.,* 2016).

The results of the study revealed no significant differences in cortisol levels among the groups (Table 5). In contrast, T4 concentrations exhibited a significant rise in the 200, 350, and 500 mg/kg groups when compared to the control (P =0.002). This increase in T4 suggests a potential modulation of thyroid function, which has been observed in response to phytochemical supplementation (Duan *et al.,* 2015). No significant differences were observed in ALT and AST levels across the groups. Similarly, sodium and phosphorus concentrations showed no significant changes. This indicates that OPE supplementation did not adversely affect liver function or electrolyte balance, further supporting its safety as a dietary supplement for rabbits.

Conclusively, dietary supplementation with the onion peel extract at levels 200, or 350 mg/kg diet enhanced growth performance, blood cholesterol levels, immune response, and antioxidant activity has positive effects on growth performance, and acts as a hypocholesterolemic agent and can beneficially affects the immunity and antioxidant indexes of fattening APRI rabbits reared under heat stress conditions Egypt.

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أداء النمو وخصائص الذبيحة والكيمياء الحيوية للدم لذكور أرانب الأبرى النامية المغذاة على علائق مكملة بمستخلص قشر البصل خلال فصل الصيف فى مصر

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تم إجراء تجربة تغذية لمدة ٨ أسابيع لدراسة تأثير إضافة مستخلص قشر البصل إلى علائق ذكور أرانب الابرى النامية على أداء النمو، وصفات الذبيحة، والمؤشرات الكيميائية الحيوية للدم خلال فصل الصيف. شملت التجربة ٣٦ أرنباً ذكراً مفطوماً (٦٤٦ ± ١٥.٣٩ جم) وزعت عشوائياً على أربع مجموعات تجريبية: مجموعة كنترول بدون إضافات، وثلاث مجموعات مكملة بمستخلص قشر البصل بجرعات ٢٠٠، و٣٥٠، و٥٠٠ مجم/كجم علف.

أظهرت النتائج أن إضافة مستخلص قشر البصل بمستويي ٢٠٠ و٣٥٠ مجم/كجم علف حسنت بشكل معنوي ($P < 0.001$) وزن الجسم عند عمر ٩ و١٣ أسبوعًا مقارنة بمجموعة الكنترول. كما عززت الإضافة أداء النمو من خلال زيادة الوزن، ومعدل النمو النسبي، ومعامل التحويل الغذائي، دون تأثير معنوي على استهلاك العلف أو صفات الذبيحة.

وفيما يخص المؤشرات الكيميائية الحيوية للدم، سجلت مستويات الكوليسترول الكلي، والكوليسترول منخفض الكثافة (LDL) ، والكوليسترول منخفض الكثافة جدًا (VLDL)انخفاضًا معنوياً ($P < 0.01$) ، مع زيادة طفيفة ($P = 0.052$) في الكوليسترول عالي الكثافة (HDL) ، بينما لم تتغير مستويات الدهون الثلاثية. كما ارتفعت مستويات البروتين الكلي في الدم بشكل معنوي مع مستويي ٢٠٠ و٣٥٠ مجم/كجم، بينما زادت مستويات الألبومين ($P < 0.05$) والجلوبيولين ($P < 0.01$)

عند ٢٠٠ مجم/كجم. تحسنت مؤشرات مضادات الأكسدة، حيث انخفضت مستويات المالونديالدهيد ($P< 0.01$) وارتفعت تركيزات كل من الكتاليز والجلوتاثيون، وخاصة عند مستويات ٢٠٠ و٥٠٠ مجم/كجم. أما بالنسبة للاستجابات المناعية، فقد زادت مستويات الجلوبيولين المناعي M في مجموعة ٢٠٠ مجم/كجم، وارتفعت مستويات الجلوبيولين المناعي G عند ٣٥٠ مجم/كجم، كما زاد نشاط الليزوزيم ($P < 0.01$) مع الجرعات ٢٠٠ و٣٥٠ مجم/كجم مقارنة بمجموعة الكنترول.

التوصية : من نتائج هذه الدراسة يمكن التوصية باستخدام مستخلص قشر البصل عند مستوى ٢٠٠ و٣٥٠ مجم/كجم علف كإضافة في علائق ذكور الأرانب أبرى النامية تحت ظروف الاجهاد الحرارى خلال فصل الصيف فى مصر لتحسين أداء النمو، وتنظيم مستويات الكوليسترول، ولتعزيز المناعة، وزيادة نشاط مضادات الأكسدة.