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THE BENEFICIAL IMPACTS OF ADDING EXTRA VIRGIN OLIVE OIL ON GROWING RABBITS DURING THE HOT SUMMER SEASON OF EGYPT.

W. Ezzat[1]; A.M. Alazab[2]; M.S. Shoeib[3]; I. A. Fathey[3]; A. M .Gomaa[4] and Nora Hamdy[4]

[1]*Poultry Breeding Department, Animal Production Research Institute, Agriculture Center, Egypt*

[2]*Rabbit Research Department, Animal Production Research Institute, Agriculture Center, Egypt*

[3]*Poultry Nutrition Department., Animal Production Research Institute, Agriculture Center, Egypt*

[4]*Animal & Poultry Production Department, Faculty of Technology and Development, Zagazig University, Zagazig, Egypt.*

Email: *dr.waheed_ezzat @yahoo.com, Ahmedgoma413 @yahoo.com.*

ABSTRACT: *Ninety six growing rabbits at 6 weeks of age with an average initial body weight of 655.15 ± 5.92, g were randomly divided into four equal groups, 24 rabbits per each group (6 replicates in each group). The first group received a basal diet without extra virgin olive oil (EVOO) and served as a control. The other three groups were fed the basal diet supplemented with 0.2, 0.4 and 0.6% EVOO /kg diet groups, respectively. The traits studied were growth performance, blood biochemical constituents, carcass, and digestion and economic efficiency of the growing rabbits under hot summer season of Egypt.*

***The present results showed that** the final body weight (FBW) and feed conversion ratio (FCR) were enhanced significantly ($P \leq 0.05$) by 10.96 % and 9.40 % respectively, in the group fed diet supplemented with 0.6% extra virgin olive oil 0.6% EVOO as compared with the control group. Hot carcass weight, dressing, and total non-carcass fat (%) were significantly ($P \leq 0.05$) improved for growing rabbits fed diets supplemented with **0**.4 and 0.6% EVOO groups as compared with those fed the control diet. Interestingly, extra virgin olive oil supplementation improved antibody titer against serum red blood cell (SRBC'S) compared with the control diet. There were significant ($P<0.05$ or 0.01) improvements in the concentration of cholesterol, glucose, creatinine, and urea as well as immunoglobulin M (IgM), and immunoglobulin G (IgG) in the blood serum, in addition to the highest coefficients of digestion of* *crude protein (CP), ether extract (EE) and digestible crude protein (DCP) and the highest (P<0.05 or 0.01) net return and the best economic efficiency and performance index for the groups of rabbits fed diet supplemented with 0.6% extra virgin olive oil, followed by those that were fed diet supplemented with 0.6% extra virgin olive oil groups, respectively, during the summer months when compared with the control group.*

Conclusively, *from these results, it could be concluded that, dietary inclusion of 0.6% EVOO could be effectively used to enhance growth performance, carcass weight, antibody titer against SRBC'S, improvements in cholesterol, glucose, creatinine, and urea, as well as, IgG and IgM in the blood serum and highest net return, best economic efficiency and performance index of growing rabbits during the summer season of Egypt.*

Keywords: Olive oil, growth performance, immune response, serum constituents, digestibility**.**

INTRODUCTION

Heat stress (HS) has become a widespread concern on the ground, which is one of the saucy environmental stressors and causes substantial economic loss in the rabbit industry. Heat stress leads to reductions in body weight gain, feed intake, and feed efficiency, as multiple damages to the health of rabbits, such as part ill use, oxidative stress, incoherent endocrine harmony, yielding immune function, and reproductive disorders, ultimately, inducing decreased production performance and increased mortality (Farghly *et al.,* 2021 and Liang *et al.,* 2022). The normal body temperature of rabbits ranges from38.5 to 39.5°C, during summer months a 12 pm of Egypt and the hieroglyph exchange ranges from 0.5 to 1.2°C. The superlative temperature territory of rabbits is 15–25°C, and the optimal humidity is 55–65%, heat stress occurs in a second the ambient temperature is higher than 30°C, and when the temperature is higher-ranking than 35°C, rabbits cannot regulate body temperature, resulting in heat failure (Li *et al.,* 2016 and Nielsen *et al.,* 2020). Rabbits have no or few sweat glands, complicating the deed of getting rid of excess heat, thereby predisposing the animals to heat stress (Oladimeji *et al.,* 2022). Heat stress results from many worlds (*e.g.,* high environmental temperature, humidity and high stocking density), which causes a tie of unfavorable swings in immune function, endocrine, blood biochemical indexes, and antioxidant capacity, thus negatively affecting the production performance (*e.g.,* growth rate, carcass, and meat quality, reproductive performance) in rabbits (Liang *et al.,* 2022).

Olive oil is very popular worldwide for its positive effects on human health (Oliveras-López *et al.,* 2014). Olive oil is responsible for the protective properties in coronary, autoimmune, and inflammatory diseases as it acts as an anticoagulant and blood pressure regulator. Other compounds such as tocopherols and polyphenols are assigned to it with powerful antioxidants, and anti-inflammatory effects (Jimenez-Lopez *et al.,* 2020). In addition, olive oil is a good source of monounsaturated fatty acids and antioxidants such as chlorophyll, carotenoids, and vitamin E. In addition, the health-promoting effects of olive oil can be returned to the high concentrations of precursor compounds and other polyphenolic antioxidants such as tyrosol, and hydroxyl tyrosol, which is not only included in the free radicals scavenging formula, but also protects the vitamin E (alpha-tocopherol) found in olive oil (Morello *et al.,* 2004).

Extra virgin olive oil (EVOO) consists mainly of triglycerides (TAG) (98%), primarily monounsaturated fatty acids (MUFA) (80%) such as oleic acid (C18:1), which are responsible for its physicochemical properties (Carranco *et al.,* 2018).Olive oil-phenolic compounds have potentially beneficial biological effects such as antimicrobial, antioxidant, and anti−inflammatory properties (Rincón‑Cervera *et al.,* 2016). Olive oil improves the blood profile, kidney toxicity (Mokhtari *et al.,* 2020), and liver damage (Alturkistani *et al.,* 2019).

Therefore, the present research was planned to explore the impacts of dietary incorporation of EVOO at various concentrations (0, 0.2, 0.4, and 0.6% /kg diet) on the performance, blood biochemical constituents, carcass, and digestion traits and economic efficiency of the growing rabbits reared under summer season of Egypt.

MATERIALS AND METHODS

Experimental site

The present study was carried out at the Rabbit Research Unit, Animal & Poultry Production Department, Faculty of Technology and Development, Zagazig University, Zagazig, Egypt.

Animals, experimental design and diets

Ninety-six growing weaned New Zealand White (NZW) rabbits, raised for 6 weeks of age with an average initial body weight of 655.15 ± 5.92, g were randomly distributed into four experimental treatments (24 rabbits/ each group) and each treatment was sub-divided 6 replicates (4 rabbits/ each replicate). The rabbits were housed in a facility with natural ventilation, each in a cage made of galvanized wire that measured 60×55×40 cm. Batteries were accommodated with feeders for pelleted rations and automatic drinkers. Diets were offered to rabbits *ad libitum* and fresh water was available all the time. The basal experimental diet was formulated to be *isonitrogenous* (17.15% CP) and *isocaloric* (2542 Kcal DE / Kg diet), and to satisfy the nutrient requirements of growing rabbits according to NRC (1977) and the Agriculture Ministry Decree recommendations (1996). The feed ingredients and chemical composition of the experimental basal diet are presented in Table (1).The treatment groups as follows: 1- Basal diet without any addition (of olive oil), (2), (3), and (4) basal diet supplemented with 0.2, 0.4 and 0.6% extra virgin olive oil (EVOO) /kg diet, respectively (ILIADA PDO Kalamata EVOO; AGRO. VI. M.S.A., Kalamata, Greece). All animals were retained under the same management, hygiene, and environmental conditions.

Fatty acid composition of extra virgin olive oil:

Samples of oil were taken to determine the fatty acid composition by using the gas-liquid chromatography (Model: variant 3300; column of. 101; temperatures of the column, injector and detector were 200, 280 and 240 °C, respectively). Fatty acids were identified by the composition of retention times with standers and expressed as percentages of fatty acid methyl ester distribution. Percentages of identifying fatty acids were determined by using of digital "Ushikata plan meter (Model DIGI PLAN 220P). The analysis of fatty acids was performed in the Laboratory of Department of Natural Products Chemistry, National Research Center, Dokki, Cairo, Egypt (Table 2).

Meteorological parameters:

Throughout the course of the experiment, temperatures and relative humidity were recorded at 1400 h, daily throughout the entire experimental period by an automatic Thermo hygrometer set in the Rabbitry. The temperature-humidity index (THI) was measured according to LPHSI (1990) as the following equation: THI= db^{o}F – ((0.55-.055 RH) (db^{o}F -58)),

Where RH is the relative humidity as a percentage, and db^{o}F is the dry bulb temperature in Fahrenheit degrees. The values of THI attained were then characterized as follows: <82 (absence of heat stress), 82 ≤ 84 (moderate heat stress), 84 ≤ 86 (severe heat stress, and 86 and more (very severe heat stress). These values followed the calculations recorded by Marai *et al.* (2002).

Growth performance:

The rabbits were individually weighed at the beginning of the experiment and then at weekly intervals. Weighing was carried out before offering the morning meal (once a week) at 8.00 h and the live body gain weight was calculated weekly. Feed consumption and feed conversion values were weekly recorded. Mortality was recorded during the experimental period from 6 to 13 weeks of age.

***Carcass traits and chemical composition of meat*:**

At the end of the experimental period (13 weeks of age), four rabbits from each treatment group were randomly chosen and fasted for 12 h before the time of slaughtering. The rabbits were individually weighed and slaughtered conferring to Islamic procedures. After bleeding, animals were weighed and skinned. After evisceration, the carcass, head, and giblets (liver, kidney, and heart) were weighed. Dressing percentage included relative weights of carcass (empty body weight without head) , giblets and head were estimated according to Steven *et al.,* (1981). Meat chemical analyses including crude protein (CP), ether extract (EE), and ash were determined according to AOAC (2000).

Digestion trials:

In the last week of the experiment (13 weeks of age), a digestibility trial was conducted using four rabbits from each treatment group, housed individually in metabolism cages that allow feces and urine separation. The preliminary period continued for 7 days and the collection period was extended for 5 days. The feces were collected daily during the collection period and sprayed with 2% boric acid for trapping any ammonia released from faces.

Table1. Feed ingredients and chemical composition of the basal diet.

Ingredients	**%**	***Calculated analysis[2] (DM, %)***	**%**
Clover hay (12.%CP)	26.50	Crude protein (CP)	17.15
Barley grain	22.70	Ether extract (EE)	2.46
Wheat bran	21.00	Digestible energy (Kcal/Kg)[3]	2541.83
Soybean meal (44%CP)	16.20	Crude fiber (CF)	12.77
Molasses	3.00	Calcium	0.88
Corn	8.30	Total phosphorus	0.65
Dicalcium phosphate	1.05	Methionine	0.44
Limestone	0.43	Lysine	0.73
DL-Methionine	0.22	Meth+Cys	0.44
Vit. and Min. Premix[1]	0.30	Available P	0.36
NaCl	0.30		
Total	**100.00**		

(1) *Each 3 kg of premix contains: Vit. A: 12,000,000 IU; Vit. D_3: 3,000,000 IU; Vit. E: 10.0 mg; Vit. K_3: 3.0 mg; Vit. B_1: 200 mg: Vit. B_2: 5.0 mg Vit. B_6: 3.0 mg: Vit. B_{12}: 15.0 mg; Biotin: 50.0 mg; Folic acid: 1.0 mg; Nicotinic acid: 35.0 mg: Pantothenic acid: 10.0 mg; Mn: 80 g; Cu: 8.8 g; Zn: 50 g; Fe: 35 g; I: 1 g; Co: 0.15g and Se: 0.3g.

(2) According to Feed Composition Tables for Animal, Poultry Feedstuffs Used in Egypt (2001).

(3) Calculated according to De Blas and Mateos (1998).

Table 2. Fatty acid composition of olive oils

Type of fatty acids	Carbon atoms	olive oil
Palmatic	**16:00**	14.73
Stearic	**18:00**	2.57
Arachdic	**20:00**	0.45
Behenic	**22:00**	0.12
Total saturated fatty acids (TSFA)		**17.87**
Palmitoleic	**16:01**	0.92
Oleic	**18:01**	69.35
Gadoleic	**20:01**	0.30
Monounsaturated fatty acids (MUSFAs), %		**70.57**
Linoleic	**18:02**	10.24
Linolenic	**18:03**	0.64
Arachidonic acid	**20:04**	0.68
Polyunsaturated fatty acids (PUSFAs), %		11.56
Total unsaturated fatty acids (TUSFAs), %		**82.13**
Total fatty acids (TFAs), %		**100.00**

At the end of the collection period, representative feces samples (25% of fresh feces/ day) were dried at 60° C for 24 hours (constant weight), then were finely ground and thoroughly mixed to ensure sample uniformity and stored until being analyzed.

Representative samples either by diets or dried feces were assigned to determine the dry matter (DM), crude protein (CP), crude fiber (CF), ash, and ether extract (EE) according to AOAC (2000). Factor 6.25 was used for calculating CP from nitrogen values.

***Blood biochemical constituents*:**

The blood samples were collected at slaughter from each rabbit to determine blood components. Serum was separated by centrifugation for 15 minutes at 3500 rpm and frozen at -20 ^{0}C. until analysis. Blood serum total proteins (TP), albumin (ALB), cholesterol (TCH), glucose (GLG), the activity of serum aspartate aminotransferase (AST), and alanine aminotransferase (ALT), creatinine, urea were calorimetrically determined using commercial kits purchased from Bio-Diagnostic, Egypt, following the same steps as described by the manufactures.

The concentration of serum triiodothyronine (T_3) and tetraiodothyronine (T_4, thyroxine), was determined using a radioimmunoassay Kit.

Immunological response efficiency:

a. Immunoglobulin IgG and IgM

Immunoglobulin concentrations of (IgG and IgM) had been decided by way of enzyme-connected Immuno-sorbent assays usage of commercial ELISA kits consistent with the manufacturer's Instructions (Sun Biomedical Technology Co., Beijing, 10039).

b. Humoral antibody titer against serm red blood cells (SRBC'S)

At 12 weeks of age, four rabbits from each treatment were immunized by intravenous injection with 0.5 ml of a 40% suspension of sheep red blood cells (SRBC'S) in sterile saline. Seven days following the antigen challenge, blood samples were collected. Approximately, 2.0 ml of blood was drawn from the right biceps femoris muscle of each rabbit.

It was allowed to clot to provide serum for antibody titer. Humoral immune response to SRBC'S was measured using a microhaemagglutination assay by the method described by Van der Zijpp and Leenstra (1980).

Economic efficiency (EEf):

The economic efficiency (EEf) of the experimental diets was estimated depending on feeding cost and price of meat. Performance index (PI) was calculated according to North (1981) as follows:

PI = Live body weight (Kg)/ Feed conversion x 100.

Statistical analysis:

The data were subjected to one-way statistical analysis according to Snedecor and Cochran (1982) applying the SAS program (SAS, 2004) using the General Liner Model Program (GLMP). The model used to be:

$$Yij = \mu + T_i + e_{ij}.$$

Where: Y_{ij} is the observation of ij, μ is the overall mean, T_i is the effect of i, (treatments) and e_{ij} is the experimental random error.

Significant differences among treatment means were separated by Duncan's new multiple-range test (Duncan, 1955).

RESULTS AND DISCUSSION

Meteorological parameters:

The results in Figure 1 show that the temperature and the humidity index (THI) was high, ranging from 91.39 to 92.72 which meaning very strong heat stress (Marai *et al.*, 2002). The relative humidity ranged from 76.78–80.15 % during the experimental period. In addition, the ambient temperature ranged from 35.49 to 36.07 ^{o}C. Heat stress related to climate change is a problem of great concern for rabbits as they are very sensitive to heat which negatively affects their physiological status. Recently natural and safe dietary supplements have been used to reduce the effects of heat stress during summer seasons Sheiha *et al.* (2020) and Abdelnour *et al.* (2020).

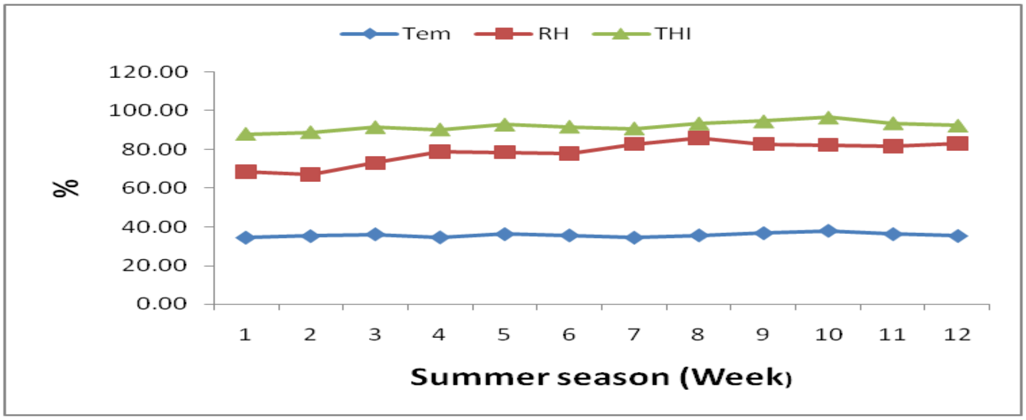

Figure 1. Calculated temperature-humidity index (THI) throughout the experimental period.

***Growth performance*:**

The results in Table (3) showed the effect of dietary supplementation with extra virgin olive oil (EVOO), during the summer months on the growth performance of growing rabbits. Results indicated that dietary supplementation with olive oil had a positive effect on the growth performance of growing rabbits during the period of high ambient temperatures. Final body weight was significantly higher in all supplemented groups than that of the control group ($P < 0.01$).

Growing rabbits supplemented with EVOO had significantly ($P < 0.05$) higher values of total gain of 8.47, 8.80, and 10.96 % throughout the experimental period as compared with the non-supplemented ones. Under the high ambient temperatures feed conversion of growing rabbits was significantly ($P<0.05$) improved by dietary supplementation with EVOO than those of the control group from 6-18 weeks of age. However, feed intake and viability rate were not significantly influenced by experimental dietary supplementations, during the experimental periods (6-13 weeks of age). It is noticed that the best values of final body weight, daily gain, total gain, and feed conversion of growing rabbits were recorded with dietary supplementation with EVOO at level 0.6 (%) when compared to the other group treatments.

Table 3. Effect of different levels of dietary supplemental olive oil on growth performance of growing rabbits exposed to high ambient temperature.

Items	Experimental groups				Sig.
	Control	**0.2%** EVOO / kg diet	**0.4%** EVOO / kg diet	**0.6%** EVOO / kg diet	
Initial weight, g	648.75 ±12.47	652.71 ±12.70	658.75 ±9.95	660.42 ±12.12	**NS**
Final weight, g	2129.75 ±33.9^{b}	2250.00 ±34.7^{a}	2269.78 ±31.3^{a}	2303.40 ±34.3^{a}	**
Daily feed intake, g	86.74 ±0.96	88.02 ±0.82	88.13 ±0.87	87.50 ±0.85	**NS**
Daily gain, g	17.65 ±0.46^{b}	19.15 ±0.44^{a}	19.21 ±0.40^{a}	19.59 ±0.42^{a}	*
Total gain, g	1482.5 ±37.93^{b}	1608.10 ±36.2^{a}	1612.96 ±33.3^{a}	1644.92 ±34.8^{a}	*
Feed conversion	4.99 ±0.12^{a}	4.66 ±0.12^{b}	4.64 ±0.10^{b}	4.52 ±0.12^{b}	*

a, b Means having different letters within the same row, differ significantly ($P \leq 0.05$) .
NS= Not significant, *=$P \leq 0.05$ and **=$P \leq 0.01$, EVOO: Extra Virgin Olive Oil

These improvements in the growth performance in growing rabbits can be attributed to the presence of polyunsaturated fatty acids (PUFA) in olive oil (11.56%) as shown in Table 3. These PUFA reduces the transit rate of chyme through the digestive system and consequently increase the absorption of nutrients, resulting in better digestibility, which ultimately improves the growth performance (Sultan *et al.*, 2015 and Awaad *et al.*, 2016). In accordance with the present results, Walaa, Salama *et al.* (2016) reported significant differences in final body weight, total weight gain and daily weight gain, and better feed conversion ratio between rabbits fed 9.9% olive cake meal and other treatments. In addition, Ashraf *et al.* (2017), investigated the effect of olive oil, black seed oil, and flaxseed oil on the growth performance of broiler chicks. They found that high weight was observed 5%, followed by the 1.0% and 0.5% olive oil treatment group, respectively when compared to treated without linseed oil.

Carcass traits and chemical composition of meat:

The results in Table (4) showed that hot carcass weight, dressing, and total non-carcass fat (%) were significantly ($P \leq 0.05$) improved for growing rabbits fed diets supplemented with EVOO at levels **0**.4 and 0.6% olive oil as compared with those fed the control diet. However, dietary supplementation had no significant effect on the percentages of liver, kidneys, heart and giblets. These

Table 4. Effect of different levels of dietary supplemental olive oil on carcass traits and chemical composition of meat of growing rabbits at 18 weeks of age exposed to high ambient temperature.

Items	Experimental groups				Sig.
	Control	**0.2%** EVOO / **kg diet**	**0.4%** EVOO / **kg diet**	**0.6%** EVOO / **kg diet**	
Hot carcass weight (%)	52.72 ±0.65[b]	54.14 ±1.03[ab]	55.72 ±0.91[a]	56.66 ±1.00[a]	*
Liver (%)	2.55 ±0.10	2.40 ±0.09	2.74 ±0.11	2.64 ±0.10	NS
Kidney (%)	0.57 ±0.04	0.53 ±0.04	0.54 ±0.05	0.55 ±0.04	NS
Heart (%)	0.31 ±0.03	0.37 ±0.03	0.37 ±0.02	0.34 ±0.04	NS
Giblets (%)	3.41 ±0.15	3.29 ±0.09	3.63 ±0.08	3.51 ±0.08	NS
Dressing (%)	56.12 ±0.79[b]	57.42 ±1.01[ab]	59.35 ±0.87[a]	60.17 ±1.01	*
Total non-carcass fat (%)	1.88 ±0.12[a]	1.59 ±0.13[ab]	1.54 ±0.09[b]	1.42 ±0.08[b]	*
Chemical composition of meat (% DM basis):					
DM	32.38 ±1.18	33.00 ±1.35	32.54 ±0.97	32.81 ±0.98	NS
CP	63.16 ±0.84[b]	64.92 ±0.77[ab]	67.42 ±0.89[a]	67.16 ±0.84[a]	*
EE	25.13 ±0.11[a]	24.45 ±0.26[b]	24.30 ±0.27[b]	24.24 ±0.17[b]	*
Ash	4.20 ±0.16	4.18 ±0.18	4.30 ±0.13	4.23 ±0.20	NS

a, b Means having different letters within the same row, differ significantly (P≤0.05) .
NS= Not significant and *=P≤0.05, EVOO: Extra Virgin Olive Oil

results are consistent with previous reports by Zakri (2016) who suggested that adding 5% or 10% olive leaves to rabbit diets may have helped improve carcass quality, and reduced the level of fat on the viscera or shoulders in the carcasses. In contrast, the addition of olive oil at different amounts to the feed (0.2, 0.4, and 0.6%), had no negative effects on carcass quality and general health, growth status of 5 to 13 week old rabbits under heat stress conditions (Shams El-Deen *et al.*, 2019). The effect of olive oil at different levels of the dietary supplement was significantly (P≤0.05) CP increased and decreased EE (P≤0.05) contents of meat as compared with those fed the control diet of developing rabbits. Conversely, dietary supplementation had no great effect on DM and Ash of meat of growing rabbits. These responses had been much like those observed by Ezzat and Saher (2012) found that dietary onion oil and onion oil plus rocket oil supplementation increased CP (P≤0.05) and decreased EE (P≤0.05) contents of meat-growing rabbits as compared with those fed the control diet.

Humeral antibody titer against serum red blood cell (SRBC'S):

The effect of olive oil at different levels of the dietary supplement during the summer months was signed (P<0.01) increased humeral antibody titer against SRBC'S in Figure 2. It is interesting to note that EVOO supplementation improved antibody titer against SRBC'S compared with the control.

These results are consistent with some data reported by **Ahmed *et al.* (2013)** observed a remarkable change in the immune response to SRBC'S antigen. This is found that broilers fed olive oil or a mixture of olive oil and canola oil had the strongest antibody response, particularly at 7 days post-challenge. Olive oil is believed to play an important role in reducing heat stress in birds under warm environmental conditions. **Alagawany *et al.* (2019)** found that olive oil is a powerful immune-modulator that can improve immunity and increase resistance to pathogens.

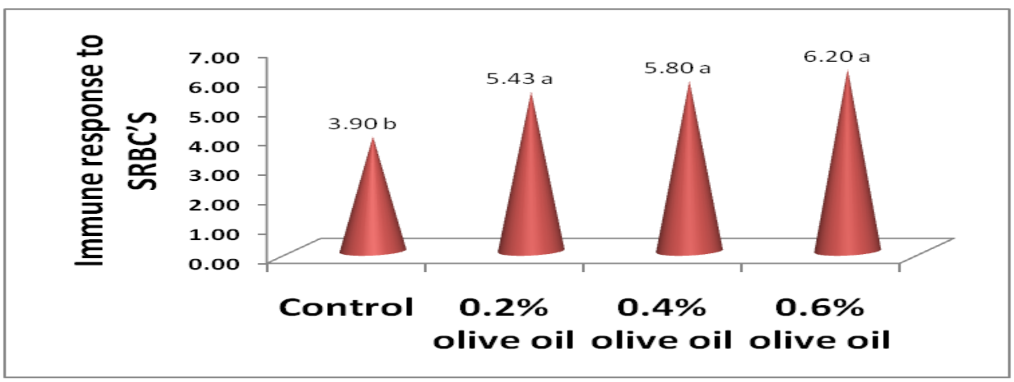

Figure 2. Effect of dietary olive oil on immunity of growing rabbits**.**

Blood biochemical

The effect of EVOO treatment on some biochemicals in the blood serum of growing rabbits in experimental groups at the end of the experiment is presented in Table 5. The current experiment revealed that no significant influence was found with EVOO treatment on blood serum parameters of growing rabbits, including total proteins, albumin, A LT, AST, T3, and T4 concentrations. However, there were significant (P<0.05 and 0.01) improvements in cholesterol, glucose, creatinine, and urea as well as IgG and IgM in the blood serum of rabbit groups during the summer months. Rashidi *et al.* (2010) reported

Table 5. Effect of different levels of dietary supplemental with EVOO on blood biochemical parameters of growing rabbits exposed to high ambient temperature.

Items	Experimental groups				
	Control	**0.2%** EVOO / kg diet	**0.4%** EVOO / kg diet	**0.6%** EVOO / kg diet	Sig
Biochemical constitutes					
Total Protein (g/dl)	5.21 ±0.22	5.73 ±0.19	5.99 ±0.21	5.87 ±0.24	**NS**
Albumin (g /dl)	3.40 ±0.17	3.11 ±0.15	3.09 ±0.19	2.84 ±0.25	**NS**
Cholesterol (mg /dl)	122.98 $\pm5.53^{a}$	118.20 $\pm6.44^{a}$	99.48 $\pm4.12^{b}$	96.94 $\pm5.00^{b}$	**
Glucose (mg/ dl)	123.32 $\pm5.57^{a}$	100.93 $\pm4.52^{b}$	106.53 $\pm4.79^{b}$	96.48 $\pm5.69^{b}$	*
Liver function					
ALT (U/L)	26.39 ±1.15	27.43 ±0.93	29.34 ±1.22	28.58 ±1.03	**NS**
AST (U/L)	33.86 ±1.40	31.71 ±1.72	30.55 ±1.19	33.80 ±2.10	**NS**
Kidney function					
Creatinine	1.92 ±0.10a	1.57 ±0.08b	1.48 ±0.11b	1.43 ±0.09b	**
Urea	11.76 ±0.49a	10.82 ±0.39ab	10.20 ±0.43b	9.96 ±0.26b	*
Thyroid hormones					
T3 (triiodothyronine)	0.94 ±0.10	0.99 ±0.14	1.13 ±0.12	1.09 ±0.09	NS
T4 (Thyroxin)	2.35 ±0.30	2.40 ±0.26	2.87 ±0.25	3.08 ±0.30	NS
Immunoglobulin (mg/dl):					
IgG	253.03 $\pm9.78^{c}$	262.69 $\pm10.6^{bc}$	287.38 $\pm11.6^{ab}$	298.54 $\pm8.80^{a}$	*
IgM	30.75 $\pm1.24^{c}$	32.38 $\pm1.02^{bc}$	34.74 $\pm1.39^{ab}$	36.93 $\pm1.16^{a}$	*

a, b, c Means having different letters within the same row, differ significantly ($P\leq0.05$) .
NS= Not significant, *=$P\leq0.05$ and **=$P\leq0.01$.

that the heat stress increases blood sugar. An increase in glucose concentration is a direct response to an increase in glucocorticoids by thermal stress (Borges *et al.,* 2007).

The present results showed significant increases in serum albumin, cholesterol, glucose, urea and creatinine in heat-stressed rabbits, while treating rabbits improved with olive oil depending on the concentration. These results agree with previous reports by Shams El-Deen *et al.* (2019) found that there was no significant effect on serum parameters of growing rabbits, including olive oil concentration of total proteins, albumin, triglycerides, HDL, creatinine, urea, IgG, IgM, T3 and T4 concentrations as well as the activity of AST and ALT activity.

On the other hand, olive oil treatment (0.2, 0.4, and 0.6%) had a significant impact ($P<0.05$) cholesterol, glucose, and LDL concentrations in the blood serum of rabbit groups. Abdelnour *et al.* (2020) reported that treating rabbits with olive oil showed significant improvement in kidney and liver functions; the active enzymes ALT, AST, and ALP decreased significantly, and the levels of total proteins and albumin increased significantly.

Digestibility coefficients and nutritive values:

The results in Table (6) show that the incorporation of EVOO in rabbit diets had no significant differences in digestion coefficients of dry matter (DM), organic matter (OM), crude fiber (CF) and nitrogen-free extract(NFE), total digestible nutrient (TDN) and digested energy (DE). However, the differences were significant ($P<.05\%$) for the digestibility coefficients of crude protein (CP), ether extract (EE), and digestible crude protein (DCP).

Rabbits fed on a 0.6% EVOO / kg diet supplemented had higher digestion coefficients of the digestibility coefficients of crude protein (CP), ether extract (EE), and digestible crude protein (DCP).

Generally, these results indicate that digestibility coefficients of nutrients and nutritional values improved by adding 0.6% olive oil/ kg diet in rabbit diets. The diets without olive oil have lower digestibility coefficients compared to those supplemented with EVOO levels. These results are consistent with those of Mehrez and Mousa (2011) observed that the digestibility coefficients of ether extract significantly increased when barely grains (0, 20, 25, or 30 %) were replaced with olive cake in the diets of growing rabbits. Walaa, salama *et al.* (2016) reported that the digestibility coefficients of EE, NFE, and DE differ significantly ($P<0.05$) after up to 60.0% of olive cake meal in the diets, The authors found that no significant differences in DM, OM, CP, CF, digestibility and the different percentages of DCP and TDN. Azazi *et al.* (2018) found that a significant increase in apparent digestibility coefficients of CF, EE, NFE, and TDN ratios were noted, while the rabbit diet showed a slight increase in DM, OM, CP,

Table 6. Digestion coefficients and nutritive values of growing rabbits as affected by dietary different levels of with EVOO exposed to high ambient temperature.

Items	Experimental grups				Sig.
	Control	**0.2%** EVOO / **kg diet**	**0.4%** EVOO / **kg diet**	**0.6%** EVOO / **kg diet**	
Digestion coefficients (%):					
DM	66.31±1.31	66.59±1.26	65.61±1.75	66.32±1.53	**NS**
OM	67.26±1.09	66.11±0.98	66.03±1.08	64.89±1.21	**NS**
Cp	64.49±1.06^{b}	66.89±1.0^{ab}	67.18±0.60^{a}	68.92±0.45^{a}	*
CF	30.48±1.45	31.97±1.36	31.54±1.39	31.85±1.59	**NS**
EE	61.34±1.29^{b}	65.69±1.0^{a}	67.58±0.70^{a}	68.09±1.20^{a}	**
NFE	65.96±1.20	67.63±1.12	67.96±0.72	67.83±0.75	**NS**
Nutritive values (%):					
TDN	56.18±1.02	57.99±0.79	58.28±0.54	58.58±0.61	**NS**
DCP	11.24^{b}±0.19	11.65^{ab}±0.19	11.71^{a}±0.11	12.02±0.08^{a}	*
DE	2489.00±44.76	2568.95±34.83	2581.78±23.65	2595.09±26.59	**NS**

a, b, c Means having different letters within the same row, differ significantly (P≤0.05)
NS= Not significant, *=P≤0.05 and **=P≤0.01, EVOO: Extra Virgin Olive Oil

DCP, and DE %, and apparent digestibility coefficient with the addition of olive cake plus citric in the rabbit diets.

Economical efficiency

Data for economic efficiency are summarized in Table (7) showing that the supplemented with 0.6% EVOO / kg diet group recorded the highest (P<0.05 and 0.01) net return, best economic efficiency and performance index followed by those fed 0.4 % EVOO / kg diet treatments as compared with the control. These results are attributed to the high (P<0.05) total weight gain of this treatment and better (P<0.05) performance index.

The results of economic efficiency support those derivatives by Mehrez and Mousa (2011) who perform that feeding priceless rabbits on a diet including 15, 20, 25, and 30 % olive pulp decreased the cost of feed per kg gain, while economic efficiency and performance index was raised with olive pulp supplementation compared with rabbits fed the control diet. Azazi *et al.* (2018) act that the best economic efficiency EE, performance index and relative economic efficiency REE were of rabbits fed diets containing 10% olive cake meal supplemented with 0.1% citric.

Table 7. The economic efficiency of growing rabbits as affected by dietary different levels of with EVOO exposed to high ambient temperature.

Items	Experimental groups				Sig
	Control	**0.2%** EVOO / **kg diet**	**0.4%** EVOO **/ kg diet**	**0.6%** EVOO **/ kg diet**	
Total feed intake (Kg)	7.28	7.37	7.40	7.35	**NS**
Price of Kg diet	8.300	8.330	8.360	8.390	**-**
Total feed cost /rabbit (LE)	60.41	61.42	61.89	61.66	**NS**
Total weight gain (Kg)	1.48^{b}	1.61^{a}	1.61^{a}	1.64^{a}	*****
Price/kg live body weight (LE)	50.00	50.00	50.00	50.00	**-**
Selling price of Kg gain **	74.13^{b}	80.40^{a}	80.65^{a}	82.25^{a}	*****
Net return/ rabbit (L.E)	13.72^{b}	18.99^{ab}	18.76^{ab}	20.58^{a}	*****
Economical efficiency(EE)¤	22.71^{b}	30.91^{ab}	30.31^{ab}	33.38^{a}	*****
Relative EE%#	100.00	136.15	133.50	147.02	
performance index (PI), %	43.49	49.26	49.79	52.01	******

a, b, Means having different letters within the same row, differ significantly ($P \leq 0.05$).
NS= Not significant and *=$P \leq 0.05$.
¤ Economic efficiency= Net return/ Total feed cost*100. Whereas net revenue= Total return - Total feed cost.
Assuming that the relative economic efficiency of the control diet equals 100 , EVOO: Extra Virgin Olive Oil

Conclusively, it could be concluded that supplemental dietary olive oils (EVOO) enhanced growth performance, and carcass weight stabilized the normal physiological balance and elevated the immunity (antibody titer against SRBC'S), as well as, immunoglobulin IgG and IgM and recorded the best economical efficiency and performance index when growing rabbits were reared under heat stress.

Thus, several benefits might be gained by adding olive oil to commercial rabbit diets, under heat stress conditions, in Egypt.

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التأثيرات المفيدة لإضافة زيت الزيتون البكر الممتاز على الأرانب النامية خلال فصل الصيف الحار في مصر

وحيد عزت[١] – احمد منير العزب[٢] – محمد صلاح شعيب[٣]- إبراهيم عبد الحميد فتحي[٣]- احمد محمد جمعه[٤]- نورا حمدي[٤]

[١]قسم بحوث تربية الدواجن- معهد بحوث الإنتاج الحيواني - مركز البحوث الزراعية – مصر

[٢]قسم بحوث تربية الأرانب- معهد بحوث الإنتاج الحيواني - مركز البحوث الزراعية – مصر

[٣]قسم بحوث تغذية الدواجن- معهد بحوث الإنتاج الحيواني - مركز البحوث الزراعية – مصر

[٤]قسم إنتاج الحيوان والدواجن - كلية التكنولوجيا والتنمية - جامعة الزقازيق - الزقازيق - مصر.

استخدام ٩٦ أرنبًا ناميًا (عمر ٦ أسابيع) تم تربيتهم خلال موسم الصيف الحار في مصر وتم تقسيمها عشوائيا إلى ٤ مجموعات تجريبية تحتوى كل مجموعة على ٢٤ أرنب.

المجموعة الأولى غذيت علي عليقه أساسية بدون إضافة زيت الزيتون البكر الممتاز واستخدمت كمجموعة كنترول. أما المجموعات الثلاث الأخرى فغذيت علي العليقه الأساسية والمضاف إليها ٠,٢ ، ٠,٤، ٠,٦٪ زيت زيتون بكر ممتاز.

أظهرت النتائج: تحسن وزن الجسم النهائي ونسبة التحويل الغذائي معنويا بنسبة ١٠,٩٦٪ ، ٠٩,٤٠٪ على التوالي في المجموعة المغذاة علي ٠,٦٪ مقارنة مع مجموعة الكنترول. كما تحسن وزن الذبيحة ونسبه والتصافي ودهن البطن (٪) معنويا علي مستوي ٠,٠٥ في الأرانب النامية والتي تتغذى على العلائق المضاف إليها زيت الزيتون بنسبة ٠,٤ ، ٠,٦٪ مقارنة مع تلك التي غذيت على عليقه الكنترول. من المثير للاهتمام أن نلاحظ أن أضافه زيت الزيتون قد حسن الاستجابة المناعية مقارنة بمجموعة الكنترول. وكان هناك تحسن معنوي علي مستوي ٠,٠٥، ٠,٠١ في تركيز الكولسترول والجلوكوز والكرياتينين واليوريا وكذلك الهيموجلوبين المناعي IgG و IgM في مصل الدم بالإضافة إلى أعلى معاملات لهضم البروتين الخام (CP) ومستخلص الأثير (EE) والبروتين الخام القابل للهضم (DCP) واعلي عائد صافي وأفضل كفاءة اقتصادية ومؤشر أداء لمجموعة الأرانب التي غذيت على ٠,٦ ٪ تليها تلك التي تم تغذيتها علي ٠,٤٪ من زيت الزيتون خلال أشهر الصيف مقارنة مع مجموعة الكنترول.

التوصية: يمكن استخدام زيت الزيتون بنسبة ٠.٦ ٪ بشكل فعال لتعزيز أداء النمو ، ووزن الذبيحة ، و الاستجابة المناعية ، وتحسين الكوليسترول ، والجلوكوز ، والكرياتينين ، واليوريا وكذلك IgG و IgM في سيرم الدم. وأعلى عائد صافى وأفضل كفاءة اقتصادية ومؤشر أداء لأرانب النمو خلال فصل الصيف