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Impact of Orally Quaffed Antioxidant on Growth, Carcass Quality, Digestibility, and Hemo-Biochemical Parameters, and Economic Efficiency of Black Balady Rabbits

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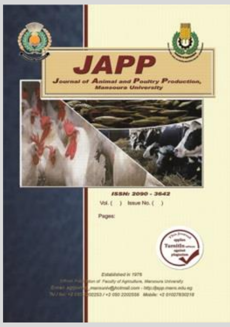

ABSTRACT

The present study aims to investigate the effects of orally quaffed antioxidant (as a source of vitamin E) throughout 7 weeks on growth performance, digestibility coefficient and carcass traits, hematological, and serum biochemical, and economic efficiency parameters of the growing black Balady rabbit males. Eighteen rabbits with an average body weight (436.75 ± 10.87 g) were randomly allotted into two experimental treatments as T_1 and T_2 (*n*=9; rabbits/treatment), which were individually subdivided into three replicates (*n*=3; rabbits/replicate). All rabbits in T_1 served as a control treatment and fed basal diet plus orally quaffed a dosage of coconut oil as a carrier material of vitamin E up to 2.0 mL / kg live body weight (LBW) / two times weekly. However, T_2 rabbits were fed the same basal diet and orally quaffed a dosage up to 2.0 mL of antioxidant (each mL contain 7 mg of vitamin E) / kg LBW/ two times weekly. The results cleared that, rabbits in T_2 significantly (P<0.05) enhanced all growth performance parameters, digestibility coefficient (%), nutritive values (%), carcass characteristics, and serum biochemical measurements compared to those in T_1. Oxidative capacity status was significantly improved in T_2 rabbits relative to T_1 rabbits. The economic efficiency and relative economic efficiency parameters were higher in T_2 than T_1 rabbits. Conclusively, orally using vitamin E as an antioxidant agent could be a useful tool for improving the productive performance, and physiological, and oxidative status parameters, besides its economic benefits for rearing native black Balady rabbits.

Keywords: Rabbit, Antioxidant, Growth, Economic efficiency

INTRODUCTION

Fortification of rabbit diet with antioxidants as vitamins at preparing feedstuffs is an important protocol to amelioration growth performance, but they might be deteriorated by pellets industry heat. Hence, supplying antioxidants as vitamins in fresh status could be helped alleviate some deleterious biochemical and biophysical factors affecting optimum reproductive and productive performance of rabbits. Intrinsically, DalleZotte and Szendro (2011) stated the antioxidant molecule is natural substances that may prevent or delay some types of cell damage and it has shown to be beneficial in preventing diseases, besides its role to inhibit the oxidation process (Liu *et al.*, 2011). Likewise, it has been shown to counteract of free radicals (FR) can cause oxidative stress (Ebeid *et al.*, 2013). Hence, there are different vitamins like A, E and C that can act the most familiar antioxidants, one of those is vitamin E (fat-soluble vitamin) which advisable in of the digestive disorders cases after weaning. In this context, Ng and Ko (2012) explained that tocotrienol and tocopherol mixed fraction is a member of the vitamin E family; both tocopherol and tocotrienol have four different isomers (alpha, beta, gamma and delta) with varying levels of biological activity post-weaning. Moreover, the most vitamins like vitamin E (α-tocopherol) naturally occur in food to prevent oxidation or to defend against different environmental stressors, as well as enhancement the total antioxidant activity (Mahmoud *et al.*, 2014). In addition, Castellini *et al.* (2007) found that vitamin E is one of the most widely vitamins used to alleviate reproduction in rabbits and it was improvement the growth performance may be attributed to the animal increased resistance during physiological status. Likewise, Aune *et al.* (2017) noticed that vitamin E protects the immune system and it has an important role in bone formation through the growth rate also, it has been proved to be a simple and convenient strategy to introduce a natural antioxidant that may effectively inhibit the oxidation reactions, as well as it led to FR scavenger in lipophilic environments (Okachi *et al.*, 2017). Accordingly, Plascencia *et al.* (2018) stated that tocopherol content of the basal diet may be reduced feed intake, enhanced growth performance and carcass characteristics of calves. In addition, Horváth and Babinszky (2019) confirmed that vitamin E has limiting agents that break oxidative chain reactions, usually by scavenging for reactive oxygen species (ROS) to prevent cellular damage thus increasing growth. Moreover, Asebe *et al.* (2020) indicated that vitamin E is also involved in the control of enzyme activity to stabilize biological cell membrane, essential for different biological body functions, and disease prevention.

Principally, the use of antioxidants during rabbit fattening could have a protective effect against microbial contamination, and mycotoxins contamination (Minardi

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et al., 2020). Beside, Adeyemo *et al.* (2021) stated that vitamin E is an important antioxidant agent that cannot be synthesized by the most mammals, thus it is required from the diet. More recently, Jain *et al.* (2022) reported that both tocopherol and tocotrienol have various health benefits, and play a major role in the functioning of growing animals, as well as maintain oxidative stability. Many authors study indirect way of using antioxidants by additive vitamins to feedstuff within different high levels, but the present study using antioxidants directly by quaff vitamins within low levels. In addition, there are backdrops to study the growth performance of black Balady rabbit's under Egyptian conditions is actually needed for meeting the protein requirements for the human population, especially in developing regions. Therefore, the present study was conducted to investigate the response of growth performance, digestibility trial, carcass characteristics, physiological responses, and oxidative status parameters, and economic evaluation of black Balady rabbits to quaff dosage of vitamin E as an antioxidant agent from the weaning to marketing weight at 12 weeks of age.

MATERIALS AND METHODS

All experimental procedures were carried out at El-Serw Experimental Research Station Domietta Governorate Egypt. The rabbits herd belongs to Animal Production Research Institute (*APRI*), Agriculture Research Center, Ministry of Agriculture, Egypt. The present study was began from January to March, 2022.

Housing of experimental rabbits and diet:

A total number of eighteen weaning black Balady male rabbits at five weeks of age with an average initial live body weight (LBW) 436.75 ± 10.87 g. All rabbits were selected randomly and distributed into two treatments as T1 and T2 (*n*=9 rabbits /treatment) used till 12 weeks of age as a selling weight. Each treatment from T1 and T2 was subdivided into three replicates (*n*=3 rabbits / replicate). At the onset of the experiment, the T1 rabbits used as control were fed basal diet plus orally quaffed (by syringe) a dosage of coconut oil as carrier material of vitamin E up to 2.0 mL / kg LBW/ two times weekly. However, T2 rabbits serviced as trial were nourished the previous basal diet and quaffed a dosage of antioxidant at levels 2.0 mL / kg LBW/ two times weekly (each mL of antioxidant contain 7.0 mg of vitamin E). Each replicate from T1 and T2 rabbits was housed in metal growing cages in dimension at 50×50×35 cm in a well-ventilated barn. Each cage was equipped with box feeding and fresh water was automatically available by stainless nipple drinker fixed in each cage.

Experimental diet:

The composition and chemical analysis of the experimental basal diet are presented in Table 1. The basal experimental diet was formulated to cover the nutrients requirements of growing rabbits from 5 to 12 weeks of age according to NRC (1977). The chemical analysis of basal diet was explained according to Feed Composition for Animal and Poultry Feedstuffs used in Egypt (2001). Furthermore, the chemical analysis of the basal diet was performed according to AOAC (2007).

Table 1. Composition and chemical analyses of the basal diet (% on dry matter basis).

Ingredient	%
Yellow Corn	8.00
Barley	20.00
Wheat bran	23.00
Soybean meal (44% crude protein)	16.00
Alfalfa hay	24.00
Mint straw	5.00
Di-calcium phosphate	1.30
Limestone	1.00
Vitamins and minerals premix*	0.30
NaCl	0.40
Di-methionine (99%)	1.00
Total	100.00
Chemical composition (%) of the basal diet	
Organic matter (OM)	91.06
Crude protein (CP)	18.17
Crude fiber (CF)	13.44
Ether extract (EE)	2.57
Nitrogen free extract (NFE)	56.88
Ash	8.94
Neutral detergent fiber (NDF)	37.75
Acid detergent fiber (ADF)	21.69
Non-fiber carbohydrates (NFC)	32.87
Calcium	1.11
Available phosphate	0.49
Lysine	0.89
Methionine	0.42
Methionine + calcium	0.66
Digestible energy (Kcal/Kg)	2784.15

*** Vitamins and minerals (premix) / kg diet included Vitamin A 160000IU, Vitamin E 125 mg, Vitamin K 17 mg, Vitamin B_1 13 mg, vitamin B_2 43 mg, Vitamin B_6 18 mg, pantothenic acid 85 mg, Vitamin B_{12} 0.17 mg, Niacin 230mg, Folic acid 12 mg, Biotin, 0.60mg, Choline Chloride 4300mg, Fe 0.34 mg, Mn 670mg, Cu 56 mg, Co 3mg, Se 2.2 mg and Zn 480 mg. Neutral detergent fiber (NDF %) = 28.924 + (0.657×CF %), and acid detergent fiber (ADF %) = 9.432+ (0.912× CF %) were calculated according to Cheeke (1987). Non-fiber carbohydrates (NFC) = 100 – (CP + NDF + EE + ash) was calculated according to Calsamiglia *et al.* (1995).**

The investigated measurements:

Growth performance:

Live body weight:

Rabbits were individually weighed every week during the experimental period in early morning at constant time. Individual live body weight (LBW, g) per replicate were totaled and divided by number of rabbits in replicate to get the average LBW per each replicate.

Daily feed intake:

The total feed intake per replicate was divided by number of rabbits in each replicate to obtain the average amount of daily feed intake (DFI, g/rabbit) as following equation;

$$\text{DFI / rabbit} = \frac{\text{Feed intake (g) / replicate / week}}{\text{No. of rabbits consumed feed during the week}}$$

Daily body weight gain:

The daily body weight gain (DBWG, g/day) was calculated as following equation;

$$\mathbf{DBWG} = \frac{\mathbf{Final\ LBW\ (g)\ -\ initial\ LBW\ (g)}}{\mathbf{Time\ between\ initial\ and\ final\ weight\ (day)}}$$

Feed conversion ratio:

The feed conversion ratio (FCR) was calculated as following equation;

$$\mathbf{FCR} = \frac{\mathbf{Feed\ amount\ (g)}}{\mathbf{Body\ weight\ gain\ (g)}}$$

Performance index:

The performance index (PI, %) was calculated as following equation;

$$PI = \frac{\text{Final LBW (kg)} \times 100}{FCR}$$

Digestibility trial:

The digestibility trial was carried out within two replicates from T_1 and T_2 rabbits (n = 6 each group; 10 week-old). Then, DFI was recorded after an adaptation period of 7 days. The hard dung output was collected in polyethylene bags for consecutive 4 days at the same time in the morning and stored at –18°C. The dung samples (100 g/day of collection/replicate) from T_1 and T_2 were partially dried at 80°C for 48 h. and used latter for chemical analysis.

The dung samples from experimental rabbits were chemically analyzed according to AOAC (2007).

Carcass quality characteristics:

At the end of the experiment, three rabbits (n=3) were randomly chosen from each treatment. Assigned rabbits were fasted for 16 hours before slaughtering and were individually weighted as pre-slaughtering weight. Rabbits were slaughtered by cutting the jugular veins of the neck using a sharp knife. When complete bleeding was achieved slaughter weight was recorded. After skinning, the carcass was opened down and all entrails were removed and the empty carcass, heart, liver, kidney spleen and testes were separately weighted, each of them was proportioned to live pre-slaughtering weight. Where, the carcass quality parameters were calculated using the following equations;

$$\text{Edible giblets (\%)} = \frac{\text{Liver} + \text{Kidney} + \text{Heart (g)}}{\text{Preslaughter weight (g)}} \times 100$$

$$\text{Total edible parts (\%)} = \frac{\text{Hot carcass weight} + \text{Edible giblets (g)}}{\text{Preslaughter weight (g)}} \times 100$$

$$\text{Dressing percentage (\%)} = \frac{\text{Hot carcass weight including the head (g)}}{\text{Live preslaughtering weight (g)}} \times 100$$

Blood parameters assaying:

At the end of the experiment (12 weeks of age), the blood samples were taken from T_1 and T_2 rabbits (n=3 in each). At the slaughter time, two separate blood samples were collected from each rabbit / treatment in sterile test tubes as either 1st aliquot with EDTA to study the hematological parameters or 2nd aliquot without EDTA to obtain the serum and to evaluate the biochemical parameters.

Hematological parameters:

Regarding to the 1st aliquot was up to 2.5 mL collected for use in hematological evaluations. The hematological parameters included the concentration of hemoglobin (Hb), hematocrit (Hct), red blood cells (RBCs), white blood cells (WBCs), blood platelets count, mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), mean corpuscular hemoglobin concentration (MCHC) and red cell distribution width (RDW) in whole blood samples. Leukocyte fraction included percentage of lymphocytes, monocytes, eosinophils, neutrophils and bosaphils was also determined. Hematological parameters were carried out according to the method of Grindem (2011) using a Hema Screen 18 automated hematology analyzer (Hospitex Diagnostics, Sesto Fiorentino, Italy).

Serum biochemical parameters:

Regarding to the 2nd aliquot, a 10 mL of blood was taken into sterile test tube and left for 20 min at room temperature to coagulate; after centrifugation at 3500 rpm for 20 min. The generated serum was isolated and placed at –20°C until used in the biochemical assays. Serum biochemical parameters included total protein, albumin, aspartate aminotransferase (AST), alanine aminotransferase (ALT), AST/ALT ratio, total cholesterol, triglycerides, high-density lipoprotein (HDL), low-density lipoprotein (LDL), and very low-density lipoprotein (VLDL) were measured. Biochemical parameters were colorimetrically determined using profitable kits (purchased from Bio-diagnostic, Egypt).

Oxidative capacity:

Serum globulin concentration was obtained by difference oxidative capacity parameters such as lipid peroxidation was evaluated through measurement of serum malondialdehyde (MDA), total antioxidant capacity (TAC) and superoxide dismutase (SOD). Serum antioxidant constituents were inspected by colorimetric procedure consuming saleable kits (Bio-diagnostic, Cairo, Egypt).

Economic feed efficiency:

Economic efficiency (EE, %) was calculated according to the prevailing prices of the experimental diets and rabbit's meat in Egypt during year of 2022. EE (%) was calculated during the experimental periods as following equations;

$$EE = \frac{\text{Price of marketing (EGP)} - \text{Total cost of feed (EGP)}}{\text{Total cost of feed (EGP)}} \times 100$$

Price of marketing (EGP) = final weight × selling price of kg rabbits.
Total cost of feed (EGP) = feed consumption (Kg/ head) × price of one Kg of feed.

While, production efficiency factor (PEF, %) was calculated according to Emmert (2000) as following equations;

$$PEF = \frac{\text{Livability} \times \text{Mass (Kg)}}{FCR \times \text{Age in days}} \times 100$$

Livability = 100 – mortality rate (%) the mortality % in this study reached to zero then the livability in this study = 100 – 0.

Mass (Kg) = Final live body weight. Age in this study = 84 days.

Statistical analysis:

Statistical evaluation of significant difference between means (mean ± SEM) were performed by T-test followed by the Duncan *post hoc* test to determine the significant differences in all the parameters among all vitamin using the SPSS/PC computer program (SPSS Statistics version, 2020). The significance among means were tested at (P<0.05). The test in a completely randomized design as the following model;

$$Y_{ijK} = \mu + T_i + R_j + e_{ijK}$$

Y_{ijk} = The observation.
μ = The overall mean.
T_i = The fixed effect of treatments (i= 1 and 2).
R_j= Replicates (j=1, 2 and 3/ treatment).
e_{ij}= Residual error.

RESULTS AND DISCUSSION

Growth performance:

The effect of quaffing rabbits in T_1 and T_2 on growth performance, and nutrients value parameters including final

LBW, DBWG, DFI, FCR, and PI of experimental rabbits is presented in Table 2. Throughout the experimental period, rabbits in T_2 have significantly (P < 0.05) higher final LBW up to 18.27% than T_1 rabbits. Rabbits in T_2 had significantly (P < 0.05) improved the DBWG during the experimental period, and outweigh of the control rabbits by 23.26%. Nevertheless, not significant (P>0.05) differences were recorded in DFI between all the experimental rabbits along the experimental period. However, the lowest (P>0.05) DFI was recorded with T_2 rabbits compared to T_1 rabbits.

Rabbits in T_2 could be evoked a significant (P<0.05) lower FCR value compared to those in T_1. The present result also showed that T_2 rabbits caused significantly (P<0.01) increasing in PI by 49.49% compared to T_1 rabbits. The metabolic weight (MW) has (P<0.05) difference in T_2 rabbits, it was surpassed by 8.89% than T_1 rabbits. In the present study, the most of MW obtained in T_2, might be attributed to the goodness nutritional status, where MW was measured to observe the nutritional status of the experimental rabbits, or in other farm animals in the previous studies as well. The current findings of growth rate are in the same line with the findings of several authors (Ebeid *et al.*, 2013, Badr, 2015, Okachi *et al.*, 2017, Asebe *et al.*, 2020 and Hassan *et al.*, 2021) they confirmed that using dietary vitamins could be resulted positively effects on growth performance of rabbits compared to non-vitamins supply. In connection with MW, Omar *et al.* (2020) stated that metabolism is the process by which body converts rations and drink into energy during this complex process, calories in ration and beverages are combined with oxygen to release the energy, which needs to body function. In addition, they explained the differences of vitamins are based on the principle role to scavenge for ROS, prevents cellular damage and improves growth performance. In generally, this study can illustrate that quaffing of antioxidant as vitamin E in T_2 rabbits could be improved all growth performance, and nutrients value parameters compared to T_1 rabbits. The results in our study tally with the notice reported by Ebeida *et al.* (2013) who revealed that enhanced growth performance with vitamin E is contented to increase serum antioxidative status and reduced oxidative stability, which refluxed on immune responsiveness in growing rabbits. The improvement of growth performance achieved with T_2 may be related to inhibitory role on the production of both prostaglandins and the enzymes involved in gluco-corticoids production, corticosterone, which negatively effects on growth performance (Dalólio *et al.*, 2015). Supplementation vitamin E with 150 ppm can have a positive effect on growth rate, and meat quality of rabbits (Cardinalia *et al.*, 2015). In the same line with the current findings, Abd- El-Moniem *et al.* (2016) stated that vitamin E has significantly higher final LBW and DBWG up to 2044.00 and 25.08 g, respectively than the control groups, which reached to 1822.00 and 21.00 g, respectively. Additionally, Okachi *et al.* (2017) found that dietary inclusion vitamin E has significant effect (P<0.05) on growth performance, and nutrients utilization parameters of treated rabbits. In the current result, the usage of additional natural antioxidant as vitamin E has beneficial effects on production performance. In this context, Asebe *et al.* (2020) recorded that 20 mg/kg diet of vitamin E has final LBW (g), DFI (g/day), DBWG (g/day) and FCR up to 1970.00, 73.52, 10.89 and 7.35 than 1805.00, 87.00, 9.27 and 9.49 in the control rabbits, respectively. Actually, the present findings indicated that greater in growth performance in T_2 than T_1 rabbits. These notice is also cleared by Dalle Zotte *et al.* (2020) who explained that vitamin E rabbits are achieved LBW (g), DFI (g/day), BWG (g) and FCR up to 3021, 155, 48.30 and 3.23 than 2956, 160, 46.70 and 3.43 in the control rabbits, respectively. Recently, Adeyemo *et al.* (2021) reported that BWG of growing rabbits fed vitamin E was numerically higher than those fed free vitamin E diet. On the other hand, enhancements in growth performance in response to dietary supplemental tocopherol, Plascencia *et al.* (2018) defined that supplemental tocopherol may enhance growth performance of calves as final BW, and BWG up to 587.00 and 1.47 kg compared to 571.00 and 1.42 kg in the control calves, respectively.

Table 2. Growth performance and nutrients value parameters of growing rabbits (7-12 weeks of age) as affected by T_1 and T_2 treatments

Parameter	The experimental treatment	
	T_1	T_2
Initial live body weight (g)	437.78±10.59	435.56±2.00
Final live body weight (g)	2099.67±63.34^b	2483.33±107.62^a
Daily body weight gain (g)	19.78±0.25^b	24.38 ±0.43^a
Daily feed intake (g)	91.69±3.88	89.51±3.46
Feed conversion ratio	4.64±0.38	3.67±0.22
Performance index (%)	45.26±1.08^b	67.66±3.63^a
Metabolic weight*	1.35±0.36^b	1.47±0.34^a

Means in the same column within each classification bearing different letters are significantly different (P<0.05).
*** Metabolic weight (MW) was calculated according to Willems *et al.* (2013), where MW = Initial body weight (kg) + final body weight (kg) ÷ $(2)^{0.75}$.**

Digestibility trial:

The apparent digestion coefficients (ADC) of OM, DM, CP, EE, NFE, ash, NDF, ADF, and NFC were higher (P>0.05) without significantly differs for the rabbits fed T_2 diet than those in T_1 (Table 3). Similarly, with the current findings Abd- El-Moniem *et al.* (2016) indicated that dietary vitamin E improved nutrients digestibility of rabbits as OM, DM, CP, EE, CF and NFE compared to those in the control group. This may be attributed to that dietary vitamins improved ADC of different nutrients by decreasing competition of gut flora of rabbit, and endogenous nitrogen losses with lowering ammonia production and stimulation of gastrointestinal cells proliferation (Kamel *et al.*, 2016), besides increase the surface area of villi, which led to improve nutrients absorption by villi, and microbial protein synthesis (El-Sanhoury, 2018). In the present study, the advantage of digestibility in T_2 rabbits is related to that vitamin E, which led to improve the digestibility via its antioxidant property as recently noticed by Abdel Dayem *et al.* (2020). Moreover, Adeyemo *et al.* (2021) confirmed that the presence of vitamin E as an antioxidant agent can cause partially interfere with oxidative protein denaturation and would improve digestibility of nutrients. In the same trend, the ADC of NDF and ADF and NFC were slight higher (P>0.05) for T_2 than T_1 rabbits this may attributed to the more digestible diet ingredients with supplied with tocopherol of vitamin E (Jain *et al.*, 2022). In the present study, other nutritive values including DCP, DEE, DCF, DNFE, TDN and DE were not significantly affected between T_1 and T_2 rabbits. However, T_2 rabbits surpass in previous nutritive values. Tocopherol and tocotrienol may be have a stimulating effect on the animal digestive system, due to the increase of digestive enzymes and improve of nutrients utilization through the enhanced growth rate (Plascencia *et al.*, 2018). Moreover, Jain *et al.* (2022) suggested that the positive stimulating effects of tocopherol and tocotrienol bioactive on the digestive system could be responsible for their enhancing effects on digestion and may have its effect through an increase in production of lactic acid bacteria, thus increasing the population of beneficial bacteria and reducing the presence of Gram-negative bacteria.

Table 3. Nutrients digestibility of growing rabbits affected by T_1 and T_2 treatments

Item	The experimental treatment T_1	T_2
Digestibility coefficient (%)		
Organic matter (OM)	65.14±0.81	67.03±0.39
Dry matter (DM)	65.61±0.88	67.84±0.36
Crude protein (CP)	74.83±0.62	75.48±0.45
Crude fiber (CF)	35.43±2.18	36.35±1.26
Ether extract (EE)	66.48±2.46	67.68±2.57
Nitrogen free extract (NFE)	69.65±0.98	71.19±0.35
Calculation of nutrient values (%)		
Neutral detergent fiber (NDF)	52.20± 3.25	52.81±4.23
Acid detergent fiber (ADF)	41.74±2.69	42.85±3.65
Non-fiber carbohydrates (NFC)	97.70±1.26	97.71±2.32
DCP	13.60±0.18	13.71±0.21
DCF	4.76± 0.02	4.89±0.03
DEE	1.71±0.001	1.74±0.003
DNFE	39.62±3.56	40.49±4.25
*TDN	61.83±5.89	63.00±6.59
** DE, (Kcal/kg)	2726.08±21.35	2777.67±33.56

To find out the digestible of crude protein (DCP) = digestibility coefficient of the CP in dung × CP content of the feedstuff /100; Digestible of crude fiber (DCF) = digestible coefficient CF in dung × CF content of the feedstuff /100; Digestible of ether extract (DEE) = digestible coefficient EE in dung × EE content of the feedstuff /100; Digestible of nitrogen free extract (DNFE) = digestibility coefficient of NFE in dung × NFE content of the feedstuff /100. * Total digestible nutrients (TDN, %) = (DCP (%) + DCF (%) + DNFE (%) + [DEE (%) × 2.25], which was calculated according to Abd- El-Moniem *et al.* (2016).Digestible energy (DE) = 44.09 × TDN, which was calculated according to NRC (1977).**

Carcass characteristics:

The current findings are revealed that insignificant (P>0.05) differences in the most carcass measurements between T_1 and T_2 rabbits. However, the data indicated that significantly (P<0.05) higher weight of pre-slaughter, hot carcass, fore part, mid part, hind part, liver, total edible giblets (%) and dressing (%) for T_2 rabbits than T_1 rabbits shown in Table 4. At the same time, the best edible main parts weight in T_2 such as fore part, mid and hind part were reached to 50.11, 512.13 and 545.28 g compared to 421.67, 416.55 and 439.33 g in T_1, respectively. The positive effects of vitamin E on the carcass quality parameters of rabbits in T_2 are strongly related with the significantly improvement of growth performance and nutrients utilization of vitamin E treated rabbits compared to those in the control treatment (T_1) as shown in Table 2. From other side, the less weight of carcass in T_1 rabbits is explained by Albonetti *et al.* (2017). The current results among rabbits in T_1 and T_2 had not significant (P>0.05) effect on weights of heart, spleen, giblets (%) and total giblets (%). Similarly, Selim *et al.* (2008) who reported that weight of pre-slaughter, carcass, dressing percentage and spleen were not significantly affected by the vitamin treatments. In addition, Amber *et al.* (2018) demonstrated that carcass traits were not significantly affected by different diet types and the lowest carcass in the control rabbits due to the less weight of rabbits (pre-slaughter weight). Furthermore, Dalle Zotte *et al.* (2020) recoded that non- significant differ among either control or vitamin treated rabbits in weight of full gastrointestinal tract, liver, perirenal fat, scapular total fat and dissectible fat, they were 18.3, 6.84, 3.21, 1.25 and 6.44 g in the control however, they reached to 18.7, 6.67, 2.64, 0.94 and 5.44 g in vitamin E treated rabbits, respectively. The current results are defined that T_2 rabbits had more (P<0.05) weight of hot carcass than T_1 rabbits. The present results are agreement with those reported by Sherif (2018) and Belles *et al.* (2019) who established that the amount of dietary vitamin E has positively correlated with that found in the hot meat carcass. In this context, Dalle Zotte *et al.* (2020) found that greater (P>0.05) weight of slaughter and chilled carcass was 3021 and 1764 g in vitamin E rabbits than 2956 and 1385 g in the control rabbits, respectively. The same authors revealed that enhancing carcass due to the positive effect of vitamin E on the absorptive capacity of the digestive tract. On the other hand, Plascencia *et al.* (2018) found that dietary tocopherol could be indicated higher hot carcass weight of calves up to 359 than 350 kg in the control ration.

Table 4. Carcass quality measurements of growing rabbits (12 weeks of age) as affected by T_1 and T_2 treatments

Parameter (g)		The experimental treatment T_1	T_2
Pre-slaughter weight		2104.65±173.2[b]	2491.87±94.93[a]
Carcass weight within following edible and giblet parts:		1444.98±150.53[b]	1779.83±107.62[a]
The best edible parts	Fore part	421.67 ±26.82[b]	500.11±17.32[a]
	Mid part	416.55±97.60[b]	512.13±31.67[a]
	Hind part	439.33 ±34.64[b]	545.28±81.29[a]
The giblet parts	Heart	5.47±0.17	5.53±0.61
	Liver	85.00±5.78[b]	101.67±4.41[a]
	Head	87.00±2.89	90.57±8.33
	Kidneys	14.20±0.70	13.76±0.54
	Spleen	0.97±0.14	1.22±0.34
	Testes	8.43±0.69	9.06±0.42
Carcass characteristics percentages	Edible giblets (%)	4.97±0.33	4.85±0.44
	Total edible giblets (%)	68.66±2.47[b]	71.43±4.12[a]
	Dressing (%)	72.70±8.22[b]	75.51±11.13[a]

Means in the same column within each classification bearing different letters are significantly different (P<0.05).

Hematological parameters:

The attained results in Table 5 indicated that count of RBCs, Hb concentration, Hct value, MCV, MCH, MCHC, blood platelets, and WBCs counts were not significantly affected between T_1 and T_2 treatments. Although, there were no significant differences between T_1

and T_2 rabbits, but T_2 rabbits indicated superiority in erythrograms or leukograms parameters compared to T_1 rabbits. These results are in agree with those observed by Abd- El-Moniem *et al.* (2016) who recoded that hematological parameters included either erythrograms or leukograms were not significantly differ in the control rabbits, or those received vitamin E. In contrast, Al-Kurdy *et al.* (2021) recently stated that increasing in RBCs count was not associated with Hb concentration in vitamin E treated rabbits. Generally, all hematological values in the present study are within the normal ranges of rabbits (Adeyemo *et al.,* 2018), where the hematological parameters are good indicators of physiological status and immune responses of animals (Zubair, 2017). In rabbits, high dietary protein quality and animal free disease correlated with enhancing count of RBCs levels, while satisfactory nutritional status was indicated by Hct value (El-Deep *et al.,* 2017). In the current study, improving most hematological parameters could be related to the strong antioxidant properties of vitamin E, which positively affected hematopoietic cells (Ayyat *et al*., 2018). The beneficial effect of vitamin E on hematological parameters may also be due to the high content of α-tocopherol, which could improve the health status of treated animals (Gouda *et al*., 2021).

Table 5. Hematological parameters of growing rabbits (12 weeks of age) as affected by T_1 and T_2 treatments

Parameter	The experimental treatment	
	T_1	T_2
RBCs ($\times10^6$/µL)	6.45±0.30	6.65±0.09
Hb (g/dL)	10.47±0.63	11.57±0.37
Hct (%)	40.00±2.37	39.97±1.13
MCV (fL)	61.93±0.75	62.87±1.61
MCH (pg)	17.77±0.24	17.07±0.541
MCHC (%)	28.67±0.23	28.33±0.13
RDW (%)	16.53±0.23	18.90±1.08
Blood platelets ($\times10^3$/mm^3)	230.67±58.77	407.33±62.69
WBCs ($\times10^3$/mm^3)	4.73 ±0.93	4.70±0.75
Leukogram fraction (%)		
Neutrophils	30.00±4.36	29.67±2.73
Lymphocytes	54.67±4.49	55.00±2.08
Monocytes	9.00±0.58	9.33±0.67
Eosinophils	3.33±0.033	3.00±0.00
Basophiles	1.00±0.00	0.67±0.33

Means in the same column within each classification bearing different letters are significantly different (P<0.05). RBCs= Red blood cells; Hb= Hemoglobin; Hct= Hematocrit; MCV= mean corpuscular volume; MCH= mean corpuscular hemoglobin; MCHC= mean corpuscular hemoglobin concentration; RDW= red cell distribution width; WBCs= white blood cells.

Serum biochemical parameters:

Rabbits in T_2 significantly (P<0.05) increased serum total protein, albumin, HDL while, it significantly decreased total cholesterol, triglycerides, LDL, AST and ALT compared to T_1 rabbits (Table 6). In this context, Hafth *et al.* (2019) revealed that rabbits treated with vitamin E showed higher (P<0.05) improvement in hematological and biochemical parameters than the control rabbits. Similarly, Gouda *et al.* (2021) recorded that serum biochemical parameters as total protein and albumin were significantly improved (P<0.01), while total cholesterol, triglycerides, ALT and AST were significantly lower (P<0.05) for rabbits fed vitamin E than those in the control group. Protein also plays an important role in many biological processes; it has an essential for growth and development, nutrients, hormone transport and immune functions (Abdel Dayem *et al.*, 2020). Where, Desoky (2018) found that vitamin E provides disease resistance by protecting leukocytes and macrophages during phagocytosis and increasing immunity responses. However, Adeyemo *et al.* (2018) observed that haematological and serum biochemistry of vitamin E inclusion diet did not significantly (P>0.05) influenced of treated rabbits. Generally, increase of blood total proteins concentrations may be related to high contents of dietary protein, essential amino acids, minerals, vitamins, phospholipids, and antioxidants (Abdel Dayem *et al.*, 2020).

Oxidative capacity:

Data in Table 6 showed that MDA concentration significantly (P<0.05) decreased, while TAC and SOD concentration significantly increased in T_2 rabbits relative to T_1 rabbits. Actually, the TAC is used to evaluate the antioxidant capacity of biological sample and it could be useful to evaluate nutritional interventions. In addition, SOD decreases ROS generation and oxidative stress and inhibits endothelial activation. In accordance with the present results, the vitamin E quaffed to T_2 rabbits could be increased TAC and SOD activity and decreased MDA activity (Abd- El-Moniem *et al.*, 2016).

Table 6. Serum biochemical and oxidative capacity parameters of growing rabbits (12 weeks of age) as affected by T_1 and T_2 treatments

Parameter	The experimental treatment	
	T_1	T_2
Total protein (g/dL)	6.60±0.26^b	7.37±0.09^a
Albumin (g/dL)	4.23±0.38^b	4.60±0.15^a
Total cholesterol (mg/dL)	55.00±4.51^a	45.33±3.53^b
Triglycerides (mg/dL)	84.67±5.24^a	80.67±17.30^b
HDL (mg/dL)	48.67±1.20^b	56.00±1.53^a
LDL (mg/dL)	120.00±2.89^a	111.00±4.16^b
VLDL (mg/dL)	16.93±1.05	16.13±3.46
AST (U/L)	75.67±8.11^a	38.33±2.91^b
ALT (U/L)	99.00±18.36^a	37.33±0.88^b
AST/ALT ratio	1.23±0.12^a	1.10±0.07^b
Oxidative capacity		
MDA (nmol/mL)	0.29±0.003^a	0.18±0.001^b
TAC (ng/mL)	0.18±0.004^b	0.31±0.005^a
SOD (µ/mL)	0.29±0.007^b	0.41±0.008^a

Means in the same column within each classification bearing different letters are significantly different (P<0.05). HDL= high-density lipoprotein; LDL= low-density lipoprotein; VLDL= very low-density lipoprotein; AST= aspartate aminotransferase; ALT= alanine aminotransferase; MDA= malondialdehyde; TAC= total antioxidant capacity; SOD= superoxide dismutase.

In this respect, El-Ratel and Gabr (2019) established that vitamin E is one of the fat-soluble vitamins, present in cell membranes, acts as an intracellular antioxidant, participates in synthesis of vitamin C, regulation of DNA metabolism and prevents the oxidation of unsaturated fatty acids. The previous authors were clarified that effects of vitamin E on the enzymatic antioxidant (*i.e.* catalase) and lipid peroxidation biomarker (*i.e.* MDA) were significantly increased when compared to the control. Vitamin E is situated at the membrane level, minimizing oxidative damage and the peroxidation of fatty acids and phospholipid components (Ebeid *et al.*, 2013). Moreover, Abd- El-Moniem *et al.* (2016) stated that using of vitamin E has significantly improved blood antioxidant status of treated rabbits. In the current results, it was also finding that vitamin E is a good indicator of improving oxidative defense system of rabbits by reducing oxidative stress and consequently decreasing lipid peroxidation as compared to the control (Adeyemo *et al*., 2018). Where, these positive effects of vitamin E as a natural antioxidant is related to it have strong activity of scavenging superoxide FR. In this respect, Ojeda *et al.* (2016) found that an increase in the consumption of diet rich in antioxidants such as vitamins increases the TAC, which reflects the joint action of the various individual antioxidants in plasma (Abdel Dayem *et al*., 2020). In addition, Gouda *et al*. (2021) suggested that vitamin E is a FR scavenger that inhibits lipid peroxidation and protects cell membranes from FR attacks, and thus maintaining cell membrane integrity, as well as it is present with high levels in immune cells.

Economic feed efficiency:

Data in Table 7 showed that EE, and EER of the weaning rabbits up to the age of marketing (12 weeks age), which were highest in case of T_2 rabbits compared to T_1 rabbits. It is also observed that calculated PEF was highest in T_2 than T_1 rabbits. These positive effects of vitamin E on EE are seriously related to its positive effects on growth performance, nutrient utilization, and digestibility parameters of treated rabbits in T_2 compared to those in the control group (T_1). The present results are in harmony with those obtained by Abd- El-Moniem *et al.* (2016) who found that vitamin E could be enhanced more the total revenue (EGP), net revenue (EGP), EE and EER (%) than in the control rabbits. In addition, Okachi *et al.* (2017) noticed that dietary vitamin E enhanced the revenue and reduced feed cost per kg of growing rabbits. Similarly, with the current findings Dalle Zotte *et al.* (2020) and Donia *et al.* (2020) stated that the highest EE was recorded with rabbits fed vitamin E compared to those fed vitamin E free diet. Likewise, Jain *et al*. (2022) recently noticed that both tocopherol and tocotrienol can provide oxidative stability that is reflected in the growth performance of animals, which consequently led to an increase in profitability.

Table 7. Economic efficiency parameters of growing rabbits (12 weeks of age) as affected by T_1 and T_2 treatments

Feed consumptions / 12 weeks/rabbit	The experimental treatment	
	T_1	T_2
Average of total feed intake (ATFI, g) = (ADFI × trail days) ^{A}	7617.96	7510.44
Total consumption of coconut oil (mL)	52.80	-
Total consumption of vitamin E (mL)	-	58.91
Cost of feed intake (EGP) = (A × price of kg)	60.94	60.08
Cost of coconut oil (EGP)	25.34	-
*Cost of vitamin E (EGP)	-	29.46
Total price of feed consumed (EGP)^{B}	86.28	89.54
Final body weight (kg)^{C}	2109.37	2490.96
Price of marketing (EGP) = (final weight × sole of rabbit kg)^{D}	105.47	124.55
Economic efficiency		
Feed efficiency $^{C/B}$	24.45	27.82
Feeding cost of producing meat rabbit $^{B/C}$	0.041	0.036
Economic efficiency (EE) amount $^{D/B}$	1.22	1.39
**EE (%) relative to the control	100.00	113.93
Production efficiency factor (PEF)	54.11	82.15

*** Vitamin E: solvent in coconut oil which produced by Ab chemical for raw pharmaceutical, Egypt.Price of sale kg of rabbit is 50 (EGP).**
Price in year 2022 for feed materials was 8000 EGP/ton, but for coconut oil 0.48 EGP /mL and vitamin E 0.50 EGP/mL. EE (%) relative to control with T_2= EE of T_2 – EE of T_1 ÷ EE of T_1×100 +100 (conceder EE of T_1 is 100%).**

CONCLUSION

Based on the current findings, the orally administration of vitamin E as an antioxidants of rabbit is beneficial to preserving growth performance, digestibility trial, boosting carcass characteristics, evidence of bioavailability of blood parameters, and stability of oxidative activity. Hence, antioxidant agents such as vitamin E could serve as an invaluable nutritional interest to rabbits, especially those reared in regions of limited resources for vitamin E deficiencies. Generally, antioxidants in the shape of vitamin E could be the best powerful health promoter for the weaned black Balady rabbits.

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تأثير تجريع مضادات الأكسدة عن طريق الفم على النمو وجودة الذبيحة والهضم ومقاييس الدم والكفاءة الاقتصادية للأرانب السوداء البلدي

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الملخص

تهدف الدراسة الحالية إلى التعرف على آثار مضادات الأكسدة التي يتم تناولها عن طريق الفم (كمصدر لفيتامين هـ) لمدة 7 أسابيع على أداء النمو، ومعامل الهضم والقيم الغذائية، وخصائص الذبيحة، وخصائص الدم، والكيمياء الحيوية في الدم، ومعايير الكفاءة الاقتصادية لذكور الأرانب البلدي السوداء المفطومة. تم تخصيص ثمانية عشر أرنبا بمتوسط وزن جسم (436.75 ± 10.87 جم) بشكل عشوائي في معاملتين (ن = 9 أرانب/معاملة)، والتي تم تقسيمها بشكل فردي إلى ثلاثة مكررات (ن = 3 أرانب/مكرره). حيث أعتبرت جميع الأرانب في المعاملة الأولي كمجموعة ضابطة غذيت على العليقة الأساسية بالإضافة إلى جرعة من زيت جوز الهند عن طريق الفم كمادة حاملة لفيتامين هـ تصل إلى 2.0 مل / كجم من وزن الجسم الحي/مرتين أسبوعيا. بينما تم تغذية الأرانب في المعاملة الثانية على نفس العليقة الأساسية وتناولت جرعة تصل إلى 2.0 مل من مضادات الأكسدة عن طريق الفم (يحتوي كل مل على 7 ملجم من فيتامين هـ) / كجم من وزن الجسم الحي/مرتين أسبوعيا. أوضحت النتائج أن الأرانب في المعاملة الثانية عززت معنويا جميع قياسات أداء النمو ومعامل الهضم (٪) والقيم الغذائية (٪) وخصائص الذبيحة والقياسات البيوكيميائية في الدم مقارنة بتلك الموجودة في المعاملة الأولي. تم تحسين حالة القدرة التأكسدية بشكل كبير في أرانب المعاملة الثانية مقارنة بالمعاملة الأولي. كانت معايير الكفاءة الاقتصادية والكفاءة الاقتصادية النسبية أعلى في المعاملة الثانية من الأرانب في المعاملة الأولي. بشكل قاطع، فإن استخدام فيتامين (هـ) عن طريق الفم كعامل مضاد للأكسدة يمكن أن يكون أداة مفيدة لتحسين الأداء الإنتاجي، ومعايير الحالة الفسيولوجية والأكسدة، إلى جانب فوائده الاقتصادية لتربية الأرانب البلدي السوداء الأصلية.