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COMPARATIVE STUDIES ON THE EFFECTS OF WATER- OR FAT-SOLUBLE ANTIOXIDANTS ON GROWTH, FEED DIGESTIBILITY, CARCASS TRAITS, BLOOD PARAMETERS AND ECONOMIC BENEFITS IN BALADI RABBITS

By

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ABSTRACT

This experiment was conducted in El-Serw Experimental Research Station,Domietta Governorate, Egypt. The experimental rabbits herd belongs to Animal Production Research Institute (*APRI*), Agriculture Research Center, Ministry of Agriculture, Egypt. The aim of this study was to favor adding either antioxidant soluble in water (As vitamin C at 3 ml) or in fats (as vitamin E up to 2 ml) per kg of live body weight (LBW) / two times /weekly for 12 weeks of age. The studying included growing, digestibility, carcass traits, blood parameters and economical efficiency of Baladi rabbits. A total of 24 male black Baladi rabbits (MBBR) aged 5 weeks were used in this study, with an average LBW of 433.67 g. The experimental MBBR were randomly allotted into two experimental groups (12 each), A1 (supplemented with water antioxidant as Vita .C) and A2 (received fat antioxidant as Vita. E) Treatments. Both A1 and A2 were individually subdivided into three replicates (4 each replicate). The obtained results indicated that LBW, daily body weight gain, feed conversion ratio and performance index of rabbits, reared up to 12 weeks post weaning, had no significant (P>0.05) differerence between A1 and A2 rabbits, but the best with A2 rabbits . Digestibility coefficient (%) and nutritive values (%) in A2 had higher values (P>0.05) than A1 rabbits. Also, the results indicated higher (P>0.05) carcass weight and better meat quality in A2 than in A1 rabbits. The blood parameters were not significantly (P>0.05) affected among either A1 or A2 rabbits hence, the advocacy of A2 rabbits. The blood oxidative capacity including malondialdehyde (MDA) concentration was decreased (P>0.05), while total antioxidant capacity (TAC) increased (P >0.05) in A2 rabbits compared with A1 rabbits. The highest net revenue (35.85 LE) and production efficiency factor (90.32%) observed with A2 rabbits

compared with 3.11 LE and 90.16% in A1 rabbits, respectively. It could be commendation that antioxidants soluble in fat (as Vita. E) Because of improved growth, digestibility, carcass traits, blood parameters and achieve the best returns in the economic efficiency of the production process of black Baladi rabbits.

Keywords:

Male black Baladi rabbits, antioxidants, growth performance, economical efficiency.

INTRODUCTION

Black Baladi rabbits (BBR), derived from native breed and an exotic one (Giant Flander breed), have good potential reproduction, well-adapted on a commercial level, had good repeatability and are achieving good progress improving **(Fatma M. Behiry *et al.*, 2021).** The feed industry has begun looking for food additives which can ensure satisfactory production performance. Researches had been conducted towards adding antioxidants suitable for rabbits feeding. In this context, **Ebeid *et al.* (2013)** found that antioxidants inhibit oxidation that can trigger cell damage and /or alter the loser structure or function. Beside, **Horváth and Babinszky (2019)** confirmed that antioxidants as vitamin types can break oxidative chain reactions, usually by scavenging reactive oxygen species (ROS) to prevent cellular damage mirror to increase growth. Thence, heating industry during pellets making could be deteriorated antioxidant supply. Therefore, fresh antioxidants could be help to meet these demands to increase the production performance. Then, immediate adding of antioxidants as vitamin C (As soluble in water) or vitamin E (as soluble in fat) might be used to improve growth performance in rabbits. Therefore, **Smitha *et al.* (2014)** reported that antioxidant soluble in water as vitamin C added to diet had positive impacts on the final weight (FW), daily weight gain (DWG) and daily feed intake (DFI) up to 2.30 kg, 15.43 gm and 42.88 kg compared to 1.92 kg, 11.14 gm and 42.23 kg in free antioxidant rabbits, respectively. Also, **Okachi *et al.* (2017)** defined that FW, DWG, DFI and daily protein intake were 1410.0, 13.6, 74.6 and 7.6 gm in rabbits given antioxidant soluble in water compared to 1400.0, 10.5, 74.9 and 6.7 gm in rabbit free of antioxidants, respectively. On the other hand, **Asebe *et al.* (2020)** recorded that antioxidant soluble in fat has more FW , DFI and BWG up to 1970.00, 73.52 and 10.89 g than 1805.00, 87.00 and 9.27 g in free rabbits, respectively. Also, **Adeyemo *et al.* (2021)** reported that FW of growing rabbits that received antioxidant soluble in fat was 747 g compared to 694 g in rabbits without antioxidant types. Recently, **Jain *et al.* (2022)**

indicated that antioxidants could control enzyme activity, body functions, tissue integrity, reproduction, disease prevention and biological systems.

Therefore, the present study was carried out to provide recommendations for the use antioxidants solubleinwaterorfat directly,and theireffecton growthperformance, digestibility, carcass characteristics, blood parameters and economic values in black Baladi rabbits.

MATERIAL 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 study was initiated from January to March, 2022.

Housing of experimental rabbits:

Twenty four males black Baladi rabbits (BBR) at five weeks of age in the average initial live body weight (LBW) of 433.64 ± 11.86 g were used up to 84 days. Rabbits were selected randomly and distributed into two groups; each received an antioxidant type (Soluble in water or in fats), 12 rabbits in each group formed A1 and A2. Either A1 or A2 rabbits were subdivided into three replicates (*n*=4 rabbits / replicate). At beginning of the study, two experimental diets were formed as follows: A1 rabbits received basal diet + orally vitamin C as antioxidant soluble in water (3.0 ml / kg LBW / two times weekly, each ml contained 5 mg of vitamin C). Whilst, A2 rabbits were fed on the previous basal diet + vitamin E orally as an antioxidant soluble in fat (2.0 ml / kg LBW/ two times weekly, each ml contained 7.0 mg of vitamin E). Each replicate from A1 and A2 rabbits was housed in metal growing cages in dimension of 60×60×40 cm in a well-ventilated barn. Each cage was equipped with box feeding and fresh water was automatically available by stainless steel nipple drinker fixed in each cage.

Experimental diet:

The composition and chemical analysis of the diet are presented in (Table 1). The basal diet was used to cover the requirements of growing rabbits from 5 to 12 weeks of age according to **NRC (1994).** The chemical analysis of basal diet was done according to **Feed Composition for Animal and Poultry Feedstuffs used in Egypt (2001).** Furthermore, the chemical analysis of diet and premix was performed according to **AOAC (2007)**.

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

Ingredients (%)	Basal diet
Yellow Corn	**8.00**
Barley	**20.00**
Wheat barley	**23.00**
Soybean meal (44% CP)	**16.00**
Alfalfa hay	**25.00**
Mint straw	**5.00**
Di-calcium phosphate	**1.20**
Limestone	**1.00**
Vitamins and minerals premix*	**0.30**
NaCl	**0.40**
Di-methionine (99%)	**1.00**
Total	**100.00**
Calcium	**1.11**
Available phosphate	**0.49**
Lysine	**0.89**
Methionine	**0.42**
Methionine + calcium	**0.66**
Calculated chemical composition (%) of the based 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**
****DE (Mcal /Kg)**	**2.51**

*** Vitamins and 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.**

[Nuetral detergent fiber (NDF %) = 28.924 + (0.657×CF %) and Acid detergent fiber (ADF %) = 9.432+ (0.912× CF %) according to Cheeke, (1987)].

Non fiber carbohydrates (NFC) = 100 – (CP + NDF + EE + ash) according to Calsamiglia *et al.* (1995).

**** Digestible energy (Mcal /kg) = 4.36-0.049×NDF was calculated according to Cheeke (1987).**

Experimental procedures:

Live body weight (LBW):

In early morning and at constant time, rabbits were individually weighed weekly through the whole trial period of 12 weeks for the nearest gram.Then, LBW /replicate were totaled and divided by number of rabbits in replicate to get the average LBW per each replicate.

Daily feed intake (DFI):

A certain amount of experimental basal diet was weighted for each replicate. At the end of certain period, the residual was weighted and subtracted from the offered amount to obtain the total feed intake per replicate. The obtained scale was divided by number of rabbits in replicate in order to obtain the average amount of DFI as following equation;

$$\text{DFI / rabbit} = \frac{\text{Feed intake (g) / replicate / week}}{\text{Number of consuming rabbits}}$$

Daily body weight gain (DBWG):

The DBWG was calculated by subtracting the average initial LBW of each replicate from the average final LBW for the same replicate during time between initial weight and final weight as following equation;

$$\text{DBWG} = \frac{\text{Final LBW (gm) - initial LBW (gm)}}{\text{No. of days between initial and final weight}}$$

Feed conversion ratio (FCR):

The FCR was calculated as grams of feed required to produce one gram of body weight gain, during a certain period as following equation;

$$\text{FCR} = \frac{\text{Feed amount (gm)}}{\text{Body weight gain (gm)}}$$

Performance index (PI):

PI was calculated as following equation;

$$\text{PI} = \frac{\text{Final live body weight (kg)} \times 100}{\text{Feed conversion ratio}}$$

Feed digestibility (FD):

The FD was recorded after an adaptation period of 7 days. In the morning, the hard dung output was collected in polyethylene bags for consecutive 4 days and stored at -18°C.The dung samples as 100 g / day of collection / replicate for A1 and A2 were partially dried at 80°C for 48 h and used latter for chemical analysis. The dry dung samples from A1 and A2 rabbits were chemically analyzed according to **AOAC (2007)**. Dry matter (DM) was measured using hot air circulation oven (Heraeus Ut20, Germany) at 105°C for 3 hours. Crude protein (CP) was measured using Kjeltec system 2100 (FOSS, Sweden). Ether extract (EE) was determined by Soxtec system 2045 (FOSS-Sweden), and Ash (Furance 6000, thermolyne, USA). Also, non-fiber carbohydrates (NFC) concentration was calculated according to **Calsamiglia *et al.* (1995)**. In addition, the NDF and ADF were calculated using the formula proposed by **Cheeke (1987)**.

Carcass characteristics and meat quality measurements:

At the end of the trial (12 weeks of age), 6 rabbits (3 rabbits / treatment) were chosen randomly and slaughtered according to the standard technique of **Cheeke (1987).** Before the slaughter time, rabbits were fasted up to 12 hours then weighed individually and slaughtered immediately. The slaughtered rabbits were bled, skinned and emptied of the digestive tract and urogenital organs before being weighted. After complete bleeding, pelt, viscera and tail were removed. Post- complete bleeding carcass and its components were weighed as edible parts. Heart, liver, kidneys and spleen were also weighed as percentage of post-slaughter weight.

The chemical composition of meat in the right hind leg was determined in A1 and A2 rabbits according to **Hassan *et al.* (2021).**

The dry matter (using an air-evacuated oven for 16^{h}), crude proteins, ether extract and ash were determined according to the **AOAC (2007)**.

Blood parameters assaying:

At slaughtering after 84 days of trial, four blood samples were taken in clean and heparinized test tubes. Blood plasma was separated by centrifugation at 3500 rpm for 15 minutes. Then, the plasma levels of glucose, total protein, albumin, triglycerides, cholesterol, high density lipoprotein (HDL) and activities of transaminases as (ALT and AST) in blood plasma were determined colorimetrically using profitable kits (purchased from Bio-diagnostic, Egypt). Total antioxidant capacity malondialdehyde (MDA) and total antioxidant capacity

(TAC) were determined by colorimetric procedure consuming saleable kits (Bio-diagnostic, Cairo, Egypt).

Economic feasibility measurements:

A partial budgeting technique was utilized to evaluate the economic impact of treatments rabbits in A1 and A2 as follows.

Total feed cost = Total feed intake per rabbit x cost of one kg diet.

The total cost was estimated by considering feeding cost as well as the expense of vitamins C or E amount quaffed in either A1 or A2 rabbits, respectively.

Total revenue = rabbit live body weight x price of LBW per kg.

Net revenue = total revenue - total cost.

Cost-benefit ratio = total cost/total revenue.

Production efficiency factor (PEF) was calculated according to **Emmert (2000)** as follows:

PEF = [Livability × Mass (kg) / FCR × Age per days] × 100.

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

Mass (kg) = Final live body weight.

FCR = Feed conversion ratio.

Age in the study= 84 days.

Statistical Analysis:

Statistical evaluation of significant differences between means (Mean ± SEM) were performed by ANOVA followed by the Duncan *post hoc* test to determine significant differences in all the parameters among A1 and A2 antioxidant types using the SPSS/PC computer program (**SPSS Statistics version 2020).** The test was in a completely randomized design as the following model; $Y_{ijK} = \mu + T_i + R_j + e_{ijK}$

Yijk = the observation.

μ = the overall mean.

T_i = the effect of antioxidant types (I= A1 and A2).

Rj= Replicates (j=1, 2 and 3/ treatment).

e_{ij}= residual error.

RESULTS AND DISCUSSION

Growth performance:

Growth parameters in A1 and A2 rabbits, as affected by orally quaffing antioxidant types were presented in (Table 2). No significant (P>0.05) differences were observed between A1 and A2 rabbits in average daily feed intake (ADFI), final live body weight (FLBW), daily body weight gain (DBWG), feed conversion ratio (FCR) , performance index (PI) and metabolic weight (MW). These results were consistent with those obtained by **Abd- El-Moniem *et al.* (2016)** who recorded non-significant values in FLBW and ABWG of antioxidant soluble in water as compared to antioxidant soluble in fat. In addition, **Sherif (2018)** found that antioxidants soluble in water has FLBW, DBWG, DFI and FCR up to 2078.0, 23.9, 90.6 gm and 3.83% while antioxidant soluble in fat showed 2141, 23.7, 92.0 gm and 3.90%, respectively.

In growing rabbits, it enhanced growth performance due to supplemental antioxidant types which have been previously reported (**Ebeid *et al.*, 2013, Badr, *et al.*, 2015, Okachi *et al.*, 2017 and Asebe *et al.*, 2020**). The use of antioxidants during rabbit rearing could have a protective effect against microbial contamination as well as the susceptibility to feed mycotoxin contamination **(Albonetti *et al.*, 2017)**. **Sayed-Ahmed *et al.* (2018)** found that more growing performance such as FLBW, DBWG and DFI were 2182, 26.44 and 116.34 gm with water antioxidant than 2019, 23.62, 116.81 gm in free antioxidant rabbits, respectively. Indeed, **Belles *et al.* (2019)** indicated that the positive impacts on growth performance in animals by antioxidants soluble in fat could be referred to prevention of the oxidative phenomena as the antioxidant can be easily incorporated into cell membranes, where it inhibits lipid peroxidation through a chain-breaking activity.Likewise, **El-Ratel and Gabr (2019)** showed that antioxidants were soluble in fat present in cell membranes and intracellularly participate in the synthesis of vitamin C, regulation of DNA metabolism and prevent the oxidation of unsaturated fatty acids. Also the previous notice is cleared by **Dalle Zotte, *et al.* (2020[b])** whom observed that antioxidants were soluble in fat supplied to rabbits improved LBW (g), DFI (g/day), BWG (g/day) and FC (%) up to 3021, 155, 48.30 and 3.23 compared to 2956, 160, 46.70 and 3.43 in free rabbits, respectively. Meanwhile, **Hassan *et al.* (2021)** suggested that antioxidant soluble in water has better FW and BWG, reached to 2040.69 and 22.84 g than 1872.33 and 20.13 g in free rabbits, respectively. Furthermore, **Al-Kurdy *et al.* (2021)** noticed that addition of antioxidant soluble in water had positive impact on growth rate by reducing blood saturated fatty acids and synthesizing amino acids that control nervous system, essential to develop tissues and neurotransmitter formation,

improving iron absorption and prevents the detrimental impact of the free radical and toxin. In addition, **Al-Kanaan *et al.* (2021)** reported that supplementation of antioxidant soluble in water increased LBW, BWG and decreased ADFI. On the other hand, **Adeyemo *et al.* (2021)** indicated that antioxidant soluble in fat as α-tocopherol was important for antioxidant constancy that cannot be synthesized by the most mammals and therefore is required from the diet. **Jain *et al.* (2022)** reported that fat-soluble antioxidants such as tocopherol and tocotrienol have a major role in the functions of growing animals, various health benefits and maintain oxidative stability. In the current study confirmed that using of antioxidant soluble in fat (As Vita. E) has better results than antioxidant soluble in water.

Table (2): Growth performance of rabbits as affected by water soluble and fat-soluble antioxidants.

Parameters	Antioxidant Types	
	A1 (Vita. C as water-soluble)	A2 (Vita. E as fat-soluble)
Initial weight, gm	431.67±8.17	435.66±2.01
FLBW, gm	2578.87±102.95	2583.53±106.62
ADFI, gm	87.49±3.43	87.55±3.44
DBWG, gm	25.56±0.45	25.57 ±0.44
FCR	3.42±0.37	3.42±0.23
PI	75.38±1.72	75.53±3.61
*MW	1.50±0.40	1.51±0.32

Means in the same row within each classification bearing non- significantly different (P>0.05).

*** Metabolic weight (MW) was calculated as: (Initial body weight (kg) + Final body weight (kg) ÷ 2)$^{0.75}$ according to Willems *et al.* (2013).**

Digestibility coefficient and nutritive values:

Results of (Table 3) indicated that there were no significant differences between group A1 and group A2 rabbits in digestibility coefficient and nutritive values, but the best was indicated with A2 rabbits. These results are consistent with those recorded by **Abd- El-Moniem *et al.* (2016)** who found that antioxidant supplied can improve digestibility nutrients. CP, CF, EE and NFE at 75.74, 36.67, 67.01 and 71.09% with fat-soluble antioxidant and 75.47, 39.35, 65.59 and 71.72% with water-soluble antioxidant as compared to 73.81, 66.91,

34.33 and 68.59 % in free rabbits, respectively. This was attributed to amelioration of protein digestibility by decreasing competition of gut flora with the rabbit for nutrients and endogenous nitrogen losses with lowering ammonia production and stimulation of gastrointestinal cells proliferation **(Kamel *et al.*, 2016, El-Sanhoury 2018, Sayed-Ahmed *et al.*, 2018, Abo-Eid *et al.*, 2019, Abdel Dayem *et al.*, 2020, Dalle Zotte, *et al.*, 2020[a] and Hassan *et al.*, 2021)**. In addition, **Adeyemo *et al.* (2021)** suggested that the presence of antioxidants including vitamins can partially interfere with oxidative protein denaturation and would improve digestibility of nutrients. Concerning nutritive energy values, group A2 rabbits had shoed lower (1.77 Mcal) value (P>0.05) in DE than group A1 rabbits (1.80 Mcal). Similarly, antioxidants soluble in water and fat could be obtained DE up to 2842 and 2831 Kcal respectively **(Abd- El-Moniem *et al.*, 2016)**. Changing nutritive energy values among A1 and A2 groups was allude to improve in the digestibility as indicated by most analytical fractions of DM,CP,CF, and EE and increased TDN in the digestion coefficients. The same trend was observed by of **Ettaib and Bahar (2021)**.

Table (3): Nutrient digestibility of rabbits as affected by water soluble and fat-soluble antioxidants.

Items	Antioxidants Types	
	A1 (Vita. C as water-soluble)	A2 (Vita. E as fat-soluble)
Digestibility Coefficient, %		
Organic matter (OM)	**65.64±0.91**	**66.13±0.38**
Dry matter (DM)	**65.71±0.89**	**67.94±0.36**
Crude protein, (CP)	**74.92±0.64**	**75.38±0.46**
Crude fiber, (CF)	**35.53±2.28**	**36.43±1.22**
Ether extract, (EE)	**66.78±2.56**	**67.44±2.47**
Nitrogen free extract, (NFE)	**69.95±0.97**	**70.24±0.37**
Ash	**34.36±3.21**	**32.87±3.24**
Calculation of Nutrient Values, %		
NDF	**52.27± 3.35**	**52.86±4.25**
ADF	**41.84±2.59**	**42.66±3.64**
NFC	**97.72±1.36**	**97.71±2.34**
DCP	**13.61±0.17**	**13.70±0.22**
DCF	**4.78± 0.02**	**4.80±0.03**
DEE	**1.72±0.001**	**1.73±0.002**

DNFE	**39.79±3.66**	**39.95±4.35**
***TDN**	**62.05±5.79**	**62.34±6.69**
Calculation of nutrient energy values, Mcal		
** **DE**	**1.80±21.45**	**1.77±33.76**

Means in the same row within each classification bearing non- significantly different (P>0.05).

To find out the digestible crude of protein (DCP) = digestibility coefficient of the CP in dung× CP content of the feedstuff /100. Digestible crude of fiber (DCF) = digestible coefficient CF in dung×CFcontent 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] according to **Abd El-Moniem *et al.* (2016).**

Digestible energy (DE) = 4.36-0.049× NDF **according Cheeke (1987).

Carcass characteristics and meat chemical composition:

Results of carcass characteristics and meat chemical composition of growing rabbits in rabbits of groups A1 and A2 as affected by antioxidants soluble in water or fat are presented in Table (4). The results show that there were no significant differences among groups A1 and A2 rabbits in carcass characteristics and meat quality. Our study was confirmed with the study conducted by **Sherif (2018)** who suggested non-significant differences in carcass parameters (%) as feet fur, carcass, lungs, kidneys, liver, total edible parts between rabbits given different antioxidants vitamin C and vitamin E.Hence, the antioxidant types given to rabbits could improve the feed efficiency and achieve desirable carcass characteristics **(Cardinali *et al.*, 2015)**. Also, **Okachi and Ani (2016)** found that antioxidant soluble in water (as vitamin C) has powerful antibacterial and antioxidant effect against enteric pathogens due to enhancement of the digestive and immune systems which is reflected on carcass weight. In addition, **Dalle Zotte *et al.* (2020[b])** recorded improvement in carcass weight of rabbits supplemented fat-soluble antioxidant (Vitamin C). It was suggested that antioxidants can scavenge the free radicals which are toxic by-products of many metabolic processes with their negative impacts on rabbit carcass parameters **(Hassan *et al.*, 2021)**.

Looking at the meat quality measurements, results indicate that no significant differences between rabbits of both treatments (P>0.05). Similar findings were described by **Dalle Zotte *et al.* (2020[b])**who reported similar effects on the meat quality due to vitamin E supplementation. Our results are partly coherent with those of **Hassan *et al.* (2021)** who reported that meat chemical composition included DM, CP and EE in rabbits antioxidants soluble in water (As vitamin C) were 26.65, 22.17 and 2.92 mg/ 100g DM as compared to 26.92, 22.20 and 3.49 mg/100g DM in diet rabbits free of antioxidants, respectively. Our results could be observed that superiority of fat-soluble compared to **water soluble** antioxidants.

Table (4): Carcass characteristics and meat quality measurements of rabbits as affected by water soluble and fat-soluble antioxidants.

Items	Antioxidants Types	
	A1 (Vita. C as water-soluble) group	A2 (Vita. E as fat-soluble) group
Carcass characteristics, gm		
Live weight pre-slaughter weight	2585.45±171.43	2591.87±94.93
Carcass weight	1765.98±145.59	1779.83±107.62
Edible, giblet parts and dressing of carcass, gm		
Fore part	495.11±17.32	503.31±17.32
Mid part	510.13±31.67	512.13±31.67
Hind part	540.28±81.29	545.28±81.29
Heart	5.31 ±0.01	5.53±0.61
Liver	101.08 ±0.55	101.67±4.41
Head	91.98 ±0.86	90.57±8.33
Kidneys	13.85 ±0.04	13.76±0.54
Spleen	1.25 ±0.01	1.22±0.34
Edible, giblet parts and dressing of carcass,%		
*Edible giblets,%	4.84±0.23	4.85±0.33
**Total edible giblets,%	71.05±9.07	71.43±7.55
***Dressing percentage	71.86±10.2	72.16±2.20
Meat quality measurements		
Moisture, %	65.15±0.15	66.14±0.16
Dry matter (DM), %	36.77±0.19	37.38±0.17

Crude protein (CP), %	**22.32±0.29**	**21.54±0.26**
Ether extract (EE),%	**2.85±0.16**	**2.96±0.18**
Ash,%	**1.91±0.08**	**1.89±0.10**

Means in the same row within each classification bearing non- significantly different (P>0.05).

***Edible Giblets %= liver (gm) + kidneys (gm) + heart (gm) / Pre-slaughter weight (gm) ×100.**

****Total edible parts(%) = Carcass wt. (gm) +edible giblets (gm) /Pre-slaughter weight (gm) ×100.**

*****Dressing percentage %= Carcass weight including the head (gm) ×100**

Live pre-slaughtering weight (gm)

Blood parameters:

Data in (Table 5) shows the effect of orally supplemented antioxidants on blood parameters of BBR at 12 weeks of age. Plasma levels of total protein, albumin, globulin, triglycerides, cholesterol, glucose, high-density lipoprotein (HDL), total antioxidant capacity (TAC) and malondialdehyde (MDA) or activity of aspartate aminotransferase (AST) and alanine aminotransferase (ALT) were not affected significantly (P>0.05) by antioxidant types. In harmony with the present results, **Sherif (2018)** found that supplemental soluble water or fat-soluble antioxidants did not change blood plasma glucose, total protein, albumin, globulin, cholesterol, triglycerides, or activity of ALT and AST. On the other hand, **Abdel Dayem *et al.* (2020)** suggested that levels of total proteins, albumin and globulin concentrations in blood may be related to the high contents of protein, essential amino acids, vitamins, minerals, phospholipids and antioxidants in diets. In the current study, it was found that antioxidant was soluble in water (A1) or fat (A2) might improve oxidative defense system by reducing oxidative stress and consequently it decrease lipid peroxidation, but the supremacy for fat-soluble antioxidants (A2 rabbits) . In this context, **Gouda *et al.* (2021)** stated that antioxidants soluble in fat are free radical scavengers that inhibit lipid peroxidation and protect cell membranes from the free radical attacks, thus maintain the cell membrane integrity that is present with high levels in immune cells.

Table (5): Blood parameters of rabbits as affected by water-soluble and fat-soluble antioxidants.

Items	**Antioxidants Types**	
	A1 (Vita. C as water-soluble) group	**A2 (Vita. E as fat-soluble) group**

Glucose, mg/dI	**118.98±10.19**	**118.11±12.36**
Total protein, g/dI	**5.89±0.66**	**5.99±0.41**
Albumin, g/dI	**3.11±0.88**	**3.16±0.42**
***Globulin, g/dI**	**2.78±0.02**	**2.83±0.02**
Cholesterol, mg/dI	**92.55±5.56**	**93.51±6.45**
Triglyceride, mg/dI	**69.99±8.96**	**70.44±9.35**
HDL, mg/dI	**30.82±6.27**	**31.54±9.26**
****LDL, mg/dI**	**47.73±5.69**	**47.88±6.62**
AST, U/I	**61.25±9.55**	**59.96±8.66**
ALT, U/I	**13.02±6.36**	**12.95±5.37**
MDA, µmol/ml	**28.15±8.27**	**27.56±7.28**
TAC, µmol/ml	**1.42± 0.12**	**1.56±0.33**

Means in the same row within each classification bearing non- significantly different (P>0.05).

*** Globulin = total protein- albumin level.**

****LDL was calculated by Friedewald's formula=LDL=Cholesterol concentration-HDL concentration - Triglyceride /5**

Economic feasibility:

As shown in (Table 6), an improvement was noticed in the average values of economical feasibility including total revenue, net revenue and production efficiency factor due to receiving growing rabbits diets supplemented with vitamin C or vitamin E (As antioxidant types).

These results were indicated in A2 rabbits tend to have improved net revenue (35.85 LE) and production efficiency factor (90.32%) as compared to 35.11 LE and 90.16% in group A1 rabbits.Out result was confirmed with **Abd-El-Moniem *et al.*(2016)**who recorded that antioxidant soluble in fat (As vitamin E) has higher total revenue and net revenue (33.72 and 20.22 LE) as compared to 33.14 and 19.79 LE with antioxidant soluble in water (as vitamin C), respectively. Ultimately, antioxidant types should be supplied to the diet of growing rabbits to enhance revenue and reduce feed cost (RFC) per kg of rabbits **(Okachi *et al.*, 2017, Sayed-Ahmed *et al.*, 2018 and Hassan *et al.* (2021).**

Table (6): Economic feasibility of rabbits as affected by water-soluble and fat-soluble antioxidants.

Items	**Antioxidant Types**	
	A1 (Vita. C as water-soluble) group	**A2 (Vita. E as fat-soluble) group**
A.V feed intake (TFI)= (DFI× trail days) [A], g	**7349.16**	**7354.20**

Total consumption of vitamin C, ml	**79.09**	**-**
Total consumption of vitamin E, ml	**-**	**58.91**
Cost of feed consumption		
Cost of feed intake= (A × price of kg), LE	**58.79**	**58.83**
***Cost of vitamin C, LE**	**35.59**	**-**
***Cost of vitamin E, LE**	**-**	**35.35**
****Total cost, LE** [B]	**94.38**	**93.73**
Economic Feasibility		
Final body weight, kg [C]	**2589.95**	**2591.55**
*****Total revenue** [D = (C × price of sale kg rabbit)]	**129.49**	**129.58**
Net revenue [D-B]	**35.11**	**35.85**
Cost-benefit ratio (CBR) [B / D × 100]	**72.89**	**72.33**
Production efficiency factor (PEF), %	**90.16**	**90.23**

*** Both vitamins C and E which produced by Ab chemical for raw pharmaceutical, Egypt.**

****Price in year 2022 for CFM was 8000 EL / ton, but for vitamin C 450 EL / litter and vitamin E 600 EL/litter.**

*****Price of sale kg rabbit is 50 (LE).**

CONCLUSION

The present study highlighted that, the oral supplementation of antioxidant types soluble in water or fat for growing rabbits improved growth performance, digestibility, carcass traits, and physical meat quality and blood parameters and had positive effect on net revenue However, in the present study, the fat soluble antioxidant as Vitamin. E was preferred to utilize in growth of native black Baladi rabbits.

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