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EFFECT OF L-ARGININE SUPPLEMENTATION IN DRINKING WATER ON PERFORMANCE OF GROWING RABBIT MALES DURING SUMMER CONDITIONS

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ABSTRACT: The present study aimed to determine the effect of L-arginine (L-Arg) supplementation in drinking water on the productive performance, biochemical traits, antioxidant status, carcass traits and economic efficiency of growing rabbit during summer conditions from July to September, 2020. Sixty male Baladi Red growing rabbits (35 days), were individually weighed and randomly divided into four equal treatment groups with five replicates (3 rabbits each). Rabbits were fed same pelleted ration *ad-libitum*. Each experimental group was supplied with drinking water from a separate container. The first group served as control (unsupplied), while the second, third and fourth groups supplemented with L-Arg in drinking water by levels 1, 2 and 3 g / L, respectively, during the experimental period (35 – 90 days of age). The results indicated that the group supplemented with 2 g L-Arg/L in drinking water had significantly improved body weight, body weight gain, performance index, relative growth rate percentage and feed conversion ratio at the end of the experimental period (90 day of age). The relative weights of pre-slaughter weight and total edible parts were significantly increased for the groups supplied with 1 and 2 g of L-Arg/L compared with other experimental groups. Triglyceride and high density lipoprotein concentrations for the group supplied with 2g L-Arg/L in drinking water recorded the significantly lowest values compared with the other groups and statistically equals with control group. Results of IgG, IgM, TAC and MDA for the group supplied with 2 g L-Arg/L were significantly improved compared with other experimental groups.

In conclusion, supplementation growing rabbit males by 2 g L-Arg/ L in drinking water could improve productive performance, immunity and economic efficiency under summer conditions.

Key words: Arginine, drinking water, growing rabbits, performance, summer condition.

INRODUCTION

Heat stress is one of the most important environmental stressors causing limitation of poultry production and reproduction performances, particularly in the hot regions of the world **(**Renaudeau et al., 2011).

Over production of free radicals (oxygen free radicals $OH^{\cdot}$ and O_2) are produced under thermal stress (Slater, 1984), causes changes in enzyme activity and metabolic disturbances (Sahin et al., 2002), impairs antioxidant status (Sahin et al., 2001) and initiates lipid peroxidation in cell membranes (Whitehead et al., 1998 and Lan et al., 2004). Temperature and humidity plays a very important role as it imposes extra stress in the ability of the animals to grow and function optimally, in the tropical regions (Ani and Okpara, 2019).

Under conditions of stress, sickness or injury this important amino acid changed in to a conditionally essential one, which means that supplemental L-Arg must come from the diet. Rezaei et al. (2013) reported that arginine has been proven to be nutritionally essentials for neonates and under stressful conditions such as weaning. Arginine is an important N carrier and precursor for amino acids, proteins and polyamines needed for immune cell proliferation. L-Arginine is a substrate for biosynthesis of many molecules including protein, nitric oxide, creatine, ornithine, glutamate, polyamines, proline, glutamine, agmatine and dimethylargininesa; thereby it serves a number of important biological and physiological functions in poultry (Khajali and Wideman, 2010). The estimate of the arginine requirement, as a percentage of the growing rabbit diet, was found to be 1.0 % (Adamson and Fisherm, 1973), 0.6 % (NRC, 1977) and 0.9% (Lebas, 1989).

Supplementation of L-Arg to poultry diets has ability to avoid the harmful effect of excessive free radicals that produced during normal metabolism under heat stress (Atakisi et al., 2009), plays a crucial role in ammonia detoxification via the hepatic urea cycle (Meijer et al., 1990). Arginine is a potent stimulator of the insulin secretion from pancreatic cells and growth hormone from the anterior pituitary gland in mammals (Flynn, et al., 2002). Balnave and Oliva (1991) showed that at an ambient temperature of 30°C the digestibility of L-Arg in diets could be significantly decreased when compared with at 18 or 21°C. Several studies indicated that L-Arg has ability to regulate blood pressure, myocardial ischemia and atherosclerosis (Dhawan et al., 2005). Oral L-Arg treatment in drinking water improves' endothelium-dependent relaxation but fails to improve cardiac function in rats with heart failure (Feng, et al., 1999). Shan et al. (2012), Zhou et al. (2012) and Delgado et al. (2010) reported that L-Arg can improve growth and productive performances, feed consumption and conversation, promote proliferation and differentiation of intestinal villus cells. Sun et al. (2020) demonstrated that the growth of weanling and young Japanese White rabbits was enhanced by addition of L-Arg, through regulating intestine microbial community, improved jejunum and ileum villi development by increasing villus height, villus height/crypt depth index, and reducing the crypt depth, which refluxed on increasing the nitrogen metabolism, protein efficiency ratio and biological value, as well as feed intake. Abo-Eid et

al. (2020) showed that the final live body weight and daily weight gain of rabbit fed arginine supplied by 0.4 g/kg diet (total L-Arg = 1g/kg diet) was insignificantly higher than the other groups supplied with 0.2, 0.6 and 0.8 g/kg diet, respectively. Also, Wu et al. (2004) demonstrated that L-Arg supplied is inadequate for maximal growth of milk-fed piglets. Thus, L-Arg nutrition remains a significant concern in both human and animal health, as well as livestock production. The objective of this study was to investigate the influence of L-arginine supplementation in drinking water on the productive performance, biochemical traits, antioxidant status, carcass traits and economic efficiency of growing rabbit males during summer conditions.

MATERIALS AND METHODS

The present study was carried out at El-Sabahia Poultry Research Station, Alexandria Governorate belonging to Animal Production Research Institute, Agricultural Research Center, Ministry of Agriculture. The experiment was conducted during summer season from the middle of July up to the middle of September 2020 to investigate the influence of L-arginine (L-Arg) supplementation in drinking water (DW) on the productive performance, biochemical traits, antioxidant status, carcass traits and economic efficiency of growing rabbit males during summer season.

Experimental design

Sixty male Baladi Red growing rabbits (weaned), at five weeks of age (35 days) with initial body weight of 629.4 ± 11.28 g. Weaned rabbits were randomly divided into four equal treatment groups with five replicates (3 rabbits each). Rabbits were housed in individual galvanized wire cages (50 cm length × 45 cm width × 40 cm high) in naturally ventilated building under the same managerial, hygienic and environmental. The light dark cycle was 18L: 6D throughout the entire experimental period.

All experimental groups were fed same pelleted ration *ad-libitum* containing 18.8 % crude protein, 13 % crude fiber and 2680 kcal DE / kg diet. The composition of the experimental diet is shown in Table (1). Each experimental group was supplied with drinking water (DW) from a separate container. Water was access *ad-libitum* for the first group and served as control (group 1). Daily, for the other experimental groups (L-Arg1, L-Arg2 and L-Arg3), fixed amount of DW (100 ml) was offered for each rabbit (1500 ml/ treatment) and supplied with 1, 2 and 3 g of L-Arg g/L of DW, respectively, at the morning after 2 h of DW starvation, then fresh DW was access *ad-libitum* through the rest of the day

Growth performance traits:

Feed intake (FI) and live body weight (LBW) were measured in replicates at weekly intervals, and the body weight gain (BWG), feed conversion ratio (FCR), crude protein intake (CPI) and the daily amount of total Arg intake (ArgI/d) was calculated (the amount of Arg intake from diet + the amount of Arg consumed through water).

Performance index (PI) was calculated according to North (1981),

(live body weight (Kg) / feed conversion ratio X 100).

Relative growth rate (RGR) was estimated according to the equation of Brody (1945):

Growth rate (%) = (W2 – W1) × 100/0.5 × (W2 + W1)

Where: W1 and W2 are body weights at early and late ages studied.

Carcass characteristics:

At the end of the growing period, five rabbits were selected around the average of each treatment for carcass evaluations. The rabbits were fasted for 12 h before slaughter. The rabbits were weighed pre-slaughter, slaughtered for complete depletion, skinned, and eviscerated. The dressed carcass free from any internal organs was weighed (hot carcass weight without the head). The hot eviscerated carcass included liver, heart and kidney were weighed. The carcass yields were calculated as a relative weight of the pre-slaughter live initial body weight of the rabbits. Appending, the percentages of the total edible parts, non-edible parts and giblets were calculated as follows: (1) Giblets (%) = kidney (%) + heart (%) + liver%. (2) Total edible parts (%) = hot carcass (%) + kidney (%) + heart (%) + liver (%). (3) Non-edible parts% = 100 - total edible parts (%).

Blood sampling and analyses

Two blood samples were withdrawn (one on heparin tube to obtain plasma and the second one without heparin to obtain serum) from the marginal ear vein. Blood was collected in the morning before feeding and placed immediately in ice. Plasma samples were obtained by centrifugation of samples at 3500 rpm for 20 minutes, and stored at –20 °C until being used for analysis. Plasma samples were analyzed for total protein (TP), albumin (Alb) and globulin (Glb), (by different) and lipid profile {total lipid (TL), triglyceride (Trig), total cholesterol (TC), high density lipoprotein (HDL), low density lipoprotein (LDL)}. The activities of serum aspartate aminotransferase (AST), alanine aminotransferase (ALT), alkaline phosphatase (ALP) were assayed by colorimetric enzymatic methods using commercial kits purchased from Bio-Diagnostic Company (Recycling Crusher-SBM®). Serum total antioxidant capacity (TAC) and Malondialdehyde (MAD) were determined according to (Erel, 2004) and Ricard *et al.* (1992), respectively. All biochemical constituents were determined using commercial kits produced by Diamond Diagnostics Company (29 Tahreer St. Dokki, Giza, Egypt). Different types of immunoglobulin in blood serum (IgG and IgM) were determined using commercial ELISA kits (Kamiya Biomedical Company, USA).

Temperature humidity index (THI) estimation

Averages indoors ambient temperature (AT,^{o}C) and relative humidity (RH,%) were daily recorded using electronic digital thermo-hygrometer. The temperature humidity index (THI) was calculated using the equation modified by Marai et al. (2001).

THI= db ^{o}C- [(0.31-0.31x RH) x (db ^{o}C - 14.4)],

Where THI= Temperature humidity index, db ^{o}C =Dry bulb temperature in Celsius, RH= Relative humidity percentage/100. The THI values classified as follow : <27.8 = absence of heat stress, 27.8 < 28.9 = moderate heat stress, 28.9 < 30.0 = severe heat stress and 30.0 and more = very sever heat stress.

Digestibility experiment

Digestibility experiments were carried out at the end of growth experiment to determine the digestibility values of dry matter (DM), organic matter (OM), crude protein (CP), crude fiber (CF) and ether extract (EE). Three animals representing each group were individually housed in metabolic cages equipped with a stainless- steel screen and 4 mm mesh to retain feces but allow free passage of

urine. The digestion experiment and the collection period lasted for 5 days in which feed intake were recorded over period. Feces was collected daily before the morning meal, weighed fresh and sprayed with 2% boric acid for trapping any ammonia released from feces and dried at 60 ◦C for 24 h in an air drying oven. The feces were then ground and mixed, stored for subsequent chemical analysis (AOAC, 1990). Feed and feces samples were chemically analyzed to determine the digestibility coefficients and nutritive values of the experimental diets.

Economic evaluation

Economic evaluation for all experimental was calculated. Economic efficiency (EE) was defined as the net revenue per unit feed and arginine cost calculated from the input-output analysis.

Statistical analysis

Data were statistically analyzed according to SAS program (SAS, 2000) using GLM Procedure. Mean differences were tested by Duncan's New Multiple range (Duncan, 1955). The following model was used to study the effect of treatments on the parameters investigated as follows:

$$Yij = \mu + Ti + eij.$$

Where: Yij = an observation, μ = overall mean, Ti = effect of L-Arginine levels (i=1,2,3) and eij = experimental random error.

RESULTS

Temperature-humidity index

The maximum values of temperature degrees (^{O}C) and relative humidity (%) recorded were 30.4±0.6, 31.6±0.6 and 31.8±1.1 ^{O}C and 83.9±4.4, 82.5±5.1 and 83.2±5.8% during July, August and September, respectively. Estimated indoors minimum and maximum THI values ranged between 25.7 and 18.7, 30.7 and 23.9 and 30.9 and 23.9 during July, August and September, respectively (Table, 2).

Growth parameters

The growth parameters of growing rabbits supplemented with L-Arg in DW under hot summer condition are presented in Table (3). The groups supplemented with 2 g L-Arg/L in DW had significantly improved BW, BWG, PI and RGR at the end of experimental period (90 day of age) compared with the other experimental groups. However, the group supplied with 3 g L-Arg/L recorded the significantly lowest values of the previous parameters.

Feed intake and feed conversion ratio

The results of total FI, CPI/d, ArgI/d and FCR are represented in (Table, 4). The amount of FI of growing rabbits supplied with 3g L-Arg/L was significantly increased during whole the experimental periods. The FI and CPI for the groups supplemented with 1 and 2 g of L-Arg/L in DW were statistically equals with the control group and significantly lowered compared with the group supplied with 3g L-Arg/L. Meanwhile, as assumed the amount of ArgI/d was significantly increased due to increasing the level of L-Arg supplementation in DW. However, supplied growing rabbit with 2g L-Agr /L in DW significantly improved FCR for the whole experimental period compared with the other experimental groups.

Carcass traits

The carcass results indicated that the relative pre-slaughter weight, hot carcass, heart, kidney and total edible parts were significantly increased for the groups supplied with 1 and 2 g of L-Arg/L compared to the control and the group supplied with 3g L-Arg/L (Table, 5). However, the relative weights of liver and total giblets did not represent any

significant change among the experimental groups.

Blood biochemical constituents

The concentration of TG for the control and the group supplied the 2g L-Arg/L in DW recorded the significantly lowest values compared with the other groups (Table, 6). The blood concentrations of HDL and LDL were statistically equal for the control and the group supplied with 2g L-Arg/L of DW and both of them recorded the significantly increased concentrations compared with the other groups. The liver function for the treated groups supplied with L-Arg was significantly improved, since the ALT activity was significantly decreased compared with the control group. However, the blood concentrations of TL, TC, AST and ALP did not represent any significant change among the experimental groups. The concentration of Alb for the control and the group supplied the 2g L-Arg/L of DW was statistically equal and both of them recorded the significantly increased concentration compared with the other groups. However, the blood concentrations of TP, Glb and Alb/Glb ratio, were statistically equal among different experimental groups. Results of IgG, IgM and TAC for the group supplied with 2 g Arg/L in DW were significantly improved compared with that recorded for the control and the group supplied with 1 g Arg/L. However, the group supplied with 3 g Arg/L was numerically lower than the groups supplied with 2 g Arg, but it is statistically equal, also it is statistically equal with the concentrations recorded for control and the group supplied with 1 g Arg/L. Meanwhile, the MDA concentration was significantly improved and recorded the lowest concentration for all groups supplied with different levels of Arg.

Digestibility coefficients values

Results of Table (8) indicated that all digestibility coefficients values were significantly improved by supplementation of L-Arg. However, the digestibility coefficients values were significantly increased by increasing the level of Arg supplementation and the best significant digestibility coefficients values were recorded for the treatment group supplied with 3 g Arg/L.

Economical efficiency

The economical efficiency (EE) of supplementation L-Arg in DW was recorded in Table (9). The results indicated that growing rabbits supplied with 2g L-Arg/L during summer environmental conditions recorded the best relative economical efficiency (REE, 132.3%) compared with the other experimental groups.

DISCUSSION

The results of THI (Table, 2) indicated that the growing rabbits exposed to very severe heat stress during the mid day of August and September (the Max. values of TIH was 30.7 and 30.9, respectively). High ambient temperature as encountered in Egypt during summer season is a major constraint factor for rabbit production and reproduction (Ahmed et al., 2005). Also, Marai et al. (2002) indicated that growing and adult rabbits exposed to more than 30 THI (severe heat stress) had adversely effects on their growth and reproductive traits and reduces the resistance to diseases, since they have few functional sweat glands and have difficulty in eliminating excess body heat. During HS gradual changes occurring in amino acid metabolism and protein pools, it is likely that the bird's amino acid requirements change during hyperthermia

(Temim et al., 2000a&b). Atakisi *et al*. (2009) reported that L-Arg supplementation to poultry diets is required to avoid the harmful influences of excessive free radicals that produced during normal metabolism and to avoid the adverse effects of HS (Attia et al., 2011). Therefore, L-Arg plays a pivotal role in poultry nutrition under different conditions. The results indicated that supplementation of Arg in DW could has ability to improve the growth performance of growing rabbits. The results showing that DW supplied with 2 g L-Arg/L improved the BW, BWG, PI and RGR at the end of experimental period (90 day of age) by 15.9, 23.5, 25.4 and 9.8 %, respectively compared with the control and those supplied with 1 g L-Ar/L under HS condition. Also, by the same level of L-Arg supplementation the best FCR was recorded. These results are in agreement with Marai et al, (2001) who indicated that average daily body gain of rabbits was found to be lower in summer than that in winter. Also, daily BWG was decreased by 18 % (Chiericato et al., 1996) and by 19.4% (Marai et al., 1994) on day 90, during summer season. However, supplemented L-Arg through DW had ability to avoid the adverse effect of HS. That improvement effect of Arg supplementation are in agreement with Attia et al. (2011) who indicated that L-Arg had ability to relieve the adverse effects of HS. Also, Gonzalez-Esquerra and Leeson (2006) reported that HS increases requirements for L-Arg compared with the requirements under normal conditions. The same results were reported by Rezaei et al. (2013) who found that arginine has been proven to be nutritionally essentials for neonates and under stressful conditions such as weaning. The improvement in growth performance may be due to L-Arg is an important N carrier and precursor for amino acids, proteins and nitric oxide (Khajali and Wideman, 2010). Also, Flynn et al. (2002) reported that L-Arg has ability to stimulate the secretion of insulin by pancreatic cells and of growth hormone by the anterior pituitary gland in mammals. Zhou et al. (2012) showed that growing rabbit diets supplemented with 0.5% of L-Arg tendency to improve productive performances. Delgado et al. (2010) indicated that rabbits supplied 0.4% L-Arg adding on top to the control diet (11.3 g/kg DM) under normal condition, showed similar weight gain, feed intake, feed efficiency and final body weight during the experimental period. Also, Sun et al. (2020) reported that addition of L-Arg enhanced the growth of weanling and young rabbit by increasing the nitrogen metabolism, protein efficiency ratio, and biological value, as well as feed intake and daily weight gain. Fouad et al. (2012) found that under stress conditions L-Arg has the ability to alleviate this stress and to normalize the growth performance. Abo-Eid et al. (2020) showed that the final live body weight and daily weight gain of rabbit supplied with addition 0.4 L-Arg g/kg diet was insignificantly higher than the other groups supplied with 0.2, 0.6 and 0.8g/kg diet, respectively. Meanwhile, the herein results indicted that there are a reduction in RGR due to increasing of L-Arg to 3 g /L in DW. That may be due to increasing L-Arg doses had an adverse effect on secretion of growth hormone. Since, Fisker et al. (1999) reported that in rats, L-Arg is known as a precursor to NO that stimulates secretion of growth hormone-releasing hormone (GHRH) and thereby increases secretion of GH. However,

GHRH then increases production of NO in somatotroph cells, which subsequently inhibits GH secretion.

Results of carcass characteristic as affected by Arg supplementation in DW during summer condition are shown in Table (5). The results showed that, addition of L-Arg by 1 and 2 g/L of drinking water significantly improved percentage of pre-slaughter, hot carcass, heart, kidney and total edible parts by 6.15 and 15.35, 4.20 and 4.88, 0.6 and 0.12 and 4.27 and 5.01%, respectively compared with control and the group supplied with 3 g L-Arg/L. However, the liver and total giblets were not differed among experimental groups. These results are in agreement with the findings obtained by Abo-Eid et al. (2020) who indicated that the heaviest pre-slaughter weight and carcass weight were recorded for the group supplied with 0.4 g L-Arg/kg diet (Total Arg= 1.0 g Arg/kg diet), while, the lowest pre-slaughter weight significantly ($P<0.05$) recorded for T5 group supplied with 0.8 g Arg/kg diet (Total L-Arg = 1.6 g L-Arg/kg diet). Oso *et al.* (2017) reported that arginine supplementation improved the relative weights of spleen and thymus of turkeys. Also, Jankowski *et al.* (2020) found that the highest Arg. Level (110% of the Lys content) had an increasing the proportion of breast muscles in the final body weight of the turkey. Ruth and Field (2013) reported that the inclusion of L-Arg has been proven to support mucosal integrity by increasing or maintaining villous height and crypt depth in pre- and post-weaning healthy piglets.

Results of Table (6 and 7) demonstrated that their is an improvement on Trig, HDL concentration for the group supplied the 2g L-Arg/L of DW compared with the other groups. Also, LDL and ALT were significantly improved for al groups supplied with different levels of L-Arg compared with the control. The present results are in harmony with the finding reported by Emadi *et al*. (2011) who indicated that inclusion 250% of L-Arg by 250% requirement in broiler chicken diets significantly reduced the concentration of serum triglyceride. Also, Al-Daraji *et al*. (2011) demonstrated that injection of Japanese quails eggs by 2% L-Arg at 0 day of incubation had significantly declined triglyceride and abdominal fat content at 42 days of age. Wu *et al*. (2011) found that White Pekin ducks diets supplemented with 1% L-Arg from 21 to 42 d of age led to a significant depressed in the hepatic activity of lipogenic enzymes at 42 d of age. Atakisi et al. (2009) found that Japanese quails fed with a diet containing L-arginine (5 mg/kg) for 30 days causes a significant decrease in blood triglyceride levels compared to the control. Also, Fouad et al. (2012) reported that chickens supplemented with L-Arg (0.25%, 0.50%, or 1.00% L-Arg for 3 weeks) had lower plasma triglyceride, total cholesterol concentrations. Fascina1 et al. (2017) indicated that higher arginine and phytogenic additive levels for brown-egg layers fed dietary digestible arginine levels: 880, 968, 1056, or 1144 mg/kg of feed × phytogenic additive levels: 0, 100, and 200 mg/kg of feed, reduced blood uric acid. Yang et al. (2016) reported that there were no effects of dietary arginine supplementation on AST levels ($p>0.05$) for brown Leghorn laying hens fed diets supplemented with 0, 8.5, or 17 mg of L-arginine/kg for 42 days. However, the current results indicated that ALP, TP, Glb, Alb/Glb ratio were not significantly differed among all experimental groups. These results compatible with Yang et al.

(2016) who demonstrated that there were no effects of dietary arginine supplementation on serum total protein for brown Leghorn laying hens fed diets supplemented with 0, 8.5, or 17 mg of L-arginine/kg for 42 days. Abo-Eid et al. (2020) results showed that rabbits received dietary arginine by total 1.2g/kg diet recorded significantly ($P<0.05$) higher value on total protein; Albumin and compared to control group and other experimental group. While, rabbits group received dietary arginine by total 1.0g/kg diet recorded significantly higher value of Alb/Glb ratio (1.9). The same results are obtained by Elmas et al. (2006) and Melillo (2007) in growing rabbits.

The herein results indicated an significant improve IgG, IgM, MDA and TAC concentration for the growing rabbits reared under summer condition and supplied with different levels of Arg through DW (Table, 7). These results are in agreement with the previous studies of many researchers. AI-Daraji and Salih (2012) reported that chickens fed L-Arg directly or indirectly by its metabolites can improve the immune response of poultry reared under conventional conditions or reared under unconventional conditions. Birmani *et al*. (2019) showed that many hormones secretion increased by arginine addition particularly the growth hormones which could enhance the immune function. Amino acids are dietary components with immune enhancing functions (Jankowski *et al.,* 2017a & b and 2018). Popovic et al. (2007) indicated that arginine utilization is minimal during resting conditions, but its uptake is increased dramatically as a result of increased CAT activity upon T-cell activation. Atakisi (2009) indicated that L-arginine supplementation could be beneficial and effective for decreasing oxidative stress, improved TAC and reduced MDA concentrations of Japanese quails. **Duan et al. (2015)** observed a significant increased on the total antioxidant capacity levels and the MDA concentration lowest in all broiler breeder tissues when a diet with 1.36% digestible arginine was fed. Yang et al. (2016) showed that 25-week-old brown Leghorn laying hens diet supplied L-arginine/kg may enhance the immune status of 25-week-old brown Leghorn laying hens. Xu et al. (2018) showed that, the concentrations of IgA and serum IgM were increased linearly or quadratically on d 42 with increasing of dietary Arg on broiler chickens. Abo-Eid et al. (2020) reported that rabbits fed dietary total arginine 1.2g/kg diet had the best immunity compared with those of control (0.6 g Arg/kg diet) and other experimental rabbits groups fed total Arg 0.8, 1.0 and 1.4g/kg diet).

Results of the digestibility coefficients values indicated that aberrant digestibility values were significantly increased by increasing the level of Arg supplementation and the significantly best digestibility coefficients values were recorded for the treatment group supplied with 3 g Arg/L. These results showed that supplementation of L-Arg improved the digestibility coefficients values that maybe due to improve the intestinal epithelial health under HS conditions. These results are in agreement with the observation of Marai et al. (2001) who reported that digestibility coefficients declined due to HS by 7.9% in dry matter, 8.1% in crude protein and 1.0% in crude fiber. Also, Ruth and Field (2013) indicated that arginine supplementation (0,5–1% w/w) to young pigs supports intestinal epithelial growth and maintains gut barrier integrity and function against

bacterial toxins. Chamorro et al. (2010) and Delgado et al. (2010) detect significant improvement on gut histology and function with dietary supplementation of Arg.

The results indicated that growing rabbits supplied with 2g L-Arg/L in DW during summer condition recorded the best REE (132.3%) compared with the other experimental groups. These results compatible with result of Abo-Eid et al. (2020) who indicated that rabbits fed diets containing arginine by 1.0 g or 1.2g/kg diet had positive effects on economic parameters.

IN CONCLUSION,

Supplementation growing rabbit males by 2 g L-Arg/ L in drinking water improve productive performance, immunity and economic efficiency and could be alleviate the adverse effect of heat stress during summer conditions.

Table (1): The basal diet formulated ingredient composition and chemical analysis of the experimental diet

Ingredients	**%**	**Calculated analysis**			
Yellow corn	6.22	Crude protein, %	18.8	L-Meth, %	0.30
Soybean meal, 44%	22.33	Crude fiber, %	13.0	TSAA, %	0.62
Wheat bran	23.33	Ether extract, %	3.0	Lys-HCl, %	0.98
Barley	15.00	Digestible energy (kcal/kg diet)	2680	L-Arg, %	1.21
Alfalfa hay	30.12	***Determined analysis (g/kg***			
Ground limestone	1.00	Dry matter	1310.9	Crude fiber	138.5
Dicalcium Phosphate	1.20	Organic matter	912.1	Ether extract	26.2
NaCl	0.50	Crude protein	172.4	Nitrogen-free extract	575.0
Vit. + min. premix*	0.30	Ash	87.9		
Total	100				

*Provides per kg of diet: Vit. A 6000 IU; Vit. D 450 IU; Vit.E 40 mg; Vit. K 1mg; Vit. B1 1mg; Vit. B2 3 mg; Vit. B3 180 mg; Vit. B6 39 mg; Folic acid 2.5 mg; Vit. B12 5 µg; Pantothenic acid 10 mg; Biotin 10 µg; Choline Chloride 1200 mg; Zn 35 mg; Fe 38 mg; Cu 5 mg; I 0.2 mg; Se 0.05 mg and Mn 15 mg

Table (2): The indoor temperature degrees ^{o}C, humidity percentages and the estimation of the Temperature humidity index (THI) during the summer of 2020

Month	Temperature degrees ^{o}C			Humidity %			THI		
	Max	Min	Avr	Max	Min	Avr	Max	Min	Avr
July	30.4 ±0.6	24.4 ±0.9	27.1 ±0.7	83.9 ±4.4	55.8 ±10.2	70.2 ±3.5	25.7 ±0.7	18.7 ±1.8	23.2 ±0.7
Aug	31.6 ±0.6	25.5 ±0.3	28.4 ±0.3	82.5 ±5.1	54. 8 ±4.8	68.9 ±3.3	30.7 ±4.7	23.9 ±5.1	27.1 ±4.5
Sept	31.8 ±1.1	24.9 ±1.5	28.1 ±0.6	83.2 ±5.8	52.2 ±7.1	69.0 ±2.71	30.9 ±5.0	23.9 ±5.4	26.8 ±4.7

THI = <27.8 = absence of heat stress; THI =27.8 – 28.9 = moderate heat stress;
THI = 29.0 – 30.0 = severe heat stress; THI = > 30.0 = very severe heat stress.

Table (3): Effect of L-arginine supplementation in drinking water on initial and final body weight, body weight gain, performance index and relative growth rate of growing rabbits during the whole experimental period

Treat	IBW, g (35 d)	FBW, g (90 d)	BWG, g (35-90 d)	PI	RGR, %
Control	6303	1973 ^{b}	1342 ^{b}	32.3 ^{b}	103.1 ^{b}
L-Arg1	627.2	2026 ^{b}	1399 ^{b}	33.9 ^{b}	103.5 ^{b}
L-Arg2	628.5	2286 ^{a}	1657 ^{a}	40.5 ^{a}	113.2 ^{a}
L-Arg3	631.4	1812 ^{c}	1181 ^{c}	27.4 ^{c}	96.6 ^{c}
SEM	1.54	25.69	26.31	0.717	0.879
P Value	0.2505	0.0001	0.0001	0.0001	0.0001

^{a,b,c} Means having different superscripts in the same column are significantly different (P<0.05). IBW and FBW: initial and final body weight. BWG: body weight gain, PI= Performance index. RGR= Relative Growth rate (%), L-Arg1 = 1g Arg/L L-Arg2 = 2g Arg/L L-Arg3 = 3g Arg/L

Table (4): Effect of L-arginine supplementation in drinking water on feed intake, feed convection ratio, daily crude protein intake and total arginine intake of growing rabbits during the whole experimental period

Treat	FI, g (35-90 d)	CPI, g /d (35-90 d)	ArgI, g/d (35-90 d)	FCR g feed/ g gain (35-90 d)
Control	4157 ^{b}	13.03 ^{b}	0.90 ^{d}	3.10 ^{b}
L-Arg1	4117 ^{b}	12.90 ^{b}	0.99 ^{c}	2.94 ^{b}
L-Arg2	4103 ^{b}	12.86 ^{b}	1.09 ^{b}	2.53 ^{c}
L-Arg3	4312 ^{a}	13.51 ^{a}	1.23 ^{a}	3.65 ^{a}
SEM	15.93	0.15	0.12	0.049
P Value	0.0001	0.0001	0.0001	0.0001

^{a,b,c} Means having different superscripts in the same column are significantly different (P<0.05). L-Arg1 = 1g Arg/L L-Arg2 = 2g Arg/L L-Arg3 = 3g Arg/L. .FI: Feed intake, FCR: feed convection ratio, CPI/d: daily crude protein intake, ArgIg/d: total daily arginine intake.

Table (5): Effect of L-arginine supplementation in drinking water on some carcass characteristic of growing rabbits reared under summer condition at the end of the experimental period

Treat	Pre-slaughter weight (g)	Hot carcass, (%)	Liver, (%)	Heart, (%)	Kidneys, (%)	Total Giblets, (%)	Total edible parts, (%)
Control	1986 [b]	51.31 [b]	3.45	0.33 [b]	0.52 [b]	4.30	55.61 [b]
L-Arg1	2108 [a]	55.51 [a]	3.42	0.39 [a]	0.56 [a]	4.37	59.88 [a]
L-Arg2	2290 [a]	56.19 [a]	3.39	0.45 [a]	0.59 [a]	4.43	60.62 [a]
L-Arg3	1819 [b]	49.16 [b]	3.44	0.31 [b]	0.53 [b]	4.29	53.44 [b]
SEM	25.42	3.52	0.05	0.25	0.30	0.12	2.56
P Value	0.0001	0.0001	0.1250	0.0001	0.0001	0.0701	0.0001

[a,b,c] Means having different superscripts in the same column are significantly different (P<0.05). Giblets (%) = Kidney (%) + Heart (%) + Liver (%). Total edible parts (%) = Hot carcass (%) + Kidney (%) + Heart (%) + Liver (%). L-Arg1 = 1g Arg/L L-Arg2 = 2g Arg/L L-Arg3 = 3g Arg/L.

Table (6): Effect of L-arginine supplementation in drinking water on some biochemical parameters of growing rabbits reared under summer condition

Treat	Total Lipid (mg/dl)	Trig (mg/dl)	Chol (mg/dl)	HDL (mg/dl)	LDL (mg/dl)	ALT (U/L)	AST (U/L)	ALP (U/L)
Control	173.3	61.3 [b]	63.3	41.3[a]	29.3 [a]	34.7 [a]	25.0	228.3
L-Arg1	267.0	126.0 [a]	57.0	19.2 [b]	14.3 [b]	24.0 [b]	25.0	268.7
L-Arg2	226.0	49.5 [b]	61.5	34.5 [a]	15.4 [b]	23.7 [b]	25.0	227.5
L-Arg3	186.3	136.7 [a]	59.7	22.8 [b]	11.0 [b]	22.3 [b]	23.7	280.3
SEM	19.06	6.57	2.57	1.39	2.04	1.89	1.13	8.97
P Value	0.1601	0.0011	0.0770	0.0007	0.0113	0.0351	0.910	0.0727

[a,b,c] Means having different superscripts in the same column are significantly different (P<0.05). L-Arg1 = 1g Arg/L L-Arg2 = 2g Arg/L L-Arg3 = 3g Arg/L.
Trig: Triglycerides, Cho: Cholesterol, HDL: high density lipoprotein, LDL: low density lipoprotein, AST: Aspartate amino transferase, ALT: Alanine amino transferase, ALP: alkaline phosphatase.

Table (7): Effect of L-arginine supplementation in drinking water on some biochemical parameters of growing rabbits reared under summer condition

Treat	total Protein (g/dl)	Albumin (Alb) (g/dl)	Globulin (Glb) (g/dl)	Alb/ Glb	IgG (mg/ml)	IgM (mg/ml)	TAC Mmol/dl	MDA nmol/dl
Control	7.34	5.14 [a]	2.20	1.42	13.70 [b]	9.20 [b]	259 [c]	2.87 [a]
L-Arg1	6.38	4.38 [b]	2.00	1.46	14.56 [b]	10.93 [b]	255 [c]	1.92 [b]
L-Arg2	7.26	5.09 [a]	2.17	1.43	19.65 [a]	14.73 [a]	449 [a]	1.90 [b]
L-Arg3	7.27	4.36 [b]	2.91	1.68	15.87 [ab]	12.67 [ab]	378 [ab]	1.98 [b]
SEM	0.21	0.11	0.26	0.06	0.939	0.892	15.2	0.093
P Value	0.1754	0.0157	0.6544	0.2293	0.0255	0.0419	0.0366	0.0201

[a,b,c] Means having different superscripts in the same column are significantly different (P<0.05). L-Arg1 = 1g Arg/L L-Arg2 = 2g Arg/L L-Arg3 = 3g Arg/L

IgG: Gamma immunoglobulin, IgM: Mu immunoglobulin, TAC: Total antioxidant capacity, MDA: Malondialdehyde.

Table (8): Effect of L-arginine supplementation in drinking water on apparent digestibility coefficients values of growing rabbits reared under summer condition

Treat	Dry matter, %	Crude Protein, %	Ether extract, %	Crude Fiber,%	Organic matter,%
Control	49.12[d]	85.27 [d]	81.92 [c]	79.18 [c]	46.37 [d]
L-Arg1	61.16[c]	87.21 [c]	86.92 [b]	84.27 [b]	59.06 [c]
L-Arg2	66.20[b]	89.74 [b]	85.26 [b]	84.87 [b]	64.64 [b]
L-Arg3	70.48 [a]	91.50[a]	90.10 [a]	88.66 [a]	69.59 [a]
SEM	0.075	0.089	0.082	0.085	0.078
P Value	0.0001	0.0001	0.0001	0.0001	0.0001

[a,b,c] Means having different superscripts in the same column are significantly different

L-Arg1 = 1g Arg/L L-Arg2 = 2g Arg/L L-Arg3 = 3g Arg/L

Table (9): Effect of L-arginine supplementation in drinking water on economic efficiency (EE) and relative economical efficiency (REE) of growing rabbits reared under summer condition

Items	Experiential groups			
	Control	**L-Arg1 (1gArg /L)**	**L-Arg2 (2gArg /L)**	**L-Arg3 (3g Arg /L)**
Body weight at marketing (kg)	1962.7	2026.3	2285.7	1812.2
Price of weaning litter (L.E)	20	20	20	20
Total feed intake at marketing (kg)	4.16	4.12	4.11	4.31
Total cost feed intake (L.E.)	24.96	24.72	24.66	25.86
Total cost of managements (L.E.)/ litter	3.0	3.0	3.0	3.0
Arginine cost	0.0	1.2	2.4	3.6
Total cost (L.E.)	47.96	48.62	50.06	52.46
Price of body weight at marketing (45 L.E.)	88.32	91.18	102.86	81.5
Net revenue (L.E.)	40.36	42.56	52.80	29.04
Economic efficiency	0.84	0.87	1.05	0.56
Relative economical efficiency (%)	100	103.6	125.0	66.0

Total cost of feed = (Total feed intake × Kg feed cost)
Total cost of managements (L.E.)/litter =cost of housing +cost of medication + cost of care
Total cost = (Total feed intake × Kg feed cost, 6 LE/kg) + Price of weaning litter +Total of managements
The Net revenue = Price body weight -Total cost price
Economical efficiency =Net revenue / Total cost
Relative Economical efficiency (%) = (Net revenue/ Total cost) x 100

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الملخص العربى

تاثير اضافة الأرجنين عن طريق مياة الشرب على الآداء الأنتاجى لذكورالأرانب النامية خلال فصل الصيف

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أجريت هذة التجربة لدراسة مدي تأثير اضافة الأرجنين عن طريق مياة الشرب لذكورالأرانب النامية علي الاداء الانتاجي، والصفات البيوكيميائية و مضادات الاكسدة في ظل ظروف الصيف الحارة من يونيو حتي اغسطس ٢٠٢٠ . تم تقسيم ٦٠ ارنب بلدي أحمر (بعد الفطام بعمر٣٥ يوم) عشوائيا الي اربع مجموعات تجربية متساوية (معاملات) كل مجموعة تتكون من خمس مكررات (٣ ارانب لكل مكررة). تم تسكين الارانب في عنبر مفتوح والاحتفاظ بها في اقفاص سلك مجلفنة مزودة بغذايات وتم تقديم الماء بصورة مستمرة عن طريق حلمات لكل معاملة على حدة بصورة منفصلة. خضعت الذكور الي ١٨ ساعة اضاءة و٦ ساعات اظلام طول الفترة التجريبية والحفاظ عليها في ظل الظروف التجريبية القياسية (الادارية والصحية). تم تغذية الارانب علي نفس العليقة الغذائية التي تحتوي علي ١٨,٨ % من البروتين الخام ، ١٣% من الالياف الخام و ٢٦٨٠ ك كالوري / كجم علف. تم تزويد كل مجموعة تجريبية بمياة الشرب بصورة منفصلة علي النحو التالي قدمت مياه شرب عادية لمجموعة المقارنة طوال فترة التجربة، بينما باقي المجموعات التجربيه ففي الصباح يتم ازالة المياه من امام الارانب لمدة ساعتين ثم يتم تزويدها بكميه ثابتة من المياة المضاف اليه الارجنين (١٠٠ ملي/ ارنب) حتي تنفذ بعد ذلك يقدم لها فى باقي اليوم مياه عاديه. أستخدمت المجموعة الاولي كمجموعة مقارنة (بدون اضافة) و المجموعة الثانية والثالثة والرابعة مضاف اليها الارجنين الي مياة الشرب بمستويات ١ و ٢ و ٣جم / لتر خلال الفترة التجريبية (٣٥ – ٩٠ يوم من العمر).

اوضحت النتائج الي ان: المجموعة المضاف اليها ٢جم ارجنين / لتر ماء قد حسنت بصورة معنوية فى وزن الجسم ، وزن الجسم المكتسب دليل ومعدل الأداء و معدل النموالكفاءة التحويلة للعلف في نهاية الفترة التجريبية (٩٠ يوم من العمر). كان هناك زيادة معنوية في الاوزان النسبية لوزن ما قبل الذبح واجمالي الاجزاء الصالحة الاكل للمجموعات المضاف اليها ١ و ٢ جم أرجنين / لتر مقارنة بالمجموعات التجريبية الاخري. الدهون الثلاثية وتركيز البروتين الدهني عالي الكثافة للمجموعة المضاف اليها ٢جم أرجنين/ لتر ماء سجلت ادني القيم بشكل ملحوظ مقارنة بالمجموعات الاخري ولكنها تساوت احصائيا مع المجموعة الاولي المقارنة. كان هناك تحسن في نتائج كلا من TAC , IgM, IgG و MDA للمجموعة المضاف اليها ٢جم أرجنين/ لتر ماء مقارنة بالمجموعات التجريبية الاخري.

الخلاصة : اضافة الأرجنين عن طريق مياة الشرب لذكورالأرانب النامية خلال فصل الصيف بنسبة ٢جم ارجنين/ لتر ماء يؤدي الي تحسن فى الاداء الانتاجي والمناعى والكفاءة الاقتصادية كما انه يساعد في تخفيف التاثير السلبي للاجهاد الحراري خلال فصل الصيف.