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EFFECT OF USING DIFFERENT DIETARY LEVELS OF ARGININE AMINO ACID ON GROWTH PERFORMANCE AND MEAT QUALITY OF GROWING RABBITS

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ABSTRACT: *The study was conducted to determine the effect of using different levels of arginine amino acid on growth performance, immunity, some biochemical parameters, digestibility, carcass traits and economic efficiency of growing New Zealand White (NZW) rabbits. Forty growing NZW rabbits of both sexes, aged 5 weeks with an average initial weight of 739.75±13.15 g were used. The animals were divided into 5 groups. Each group has 4 replicates. Formulated diets of 17% crude protein (CP) were used. The experimental groups were: control or basal diet contains recommended dietary arginine (Arg.) by 0.6g/ kg diet (T_1). Then this basal diet supplemented with arginine by 0.2g/kg diet (T_2); 0.4g/kg diet (T_3); 0.6g/kg diet (T_4) and 0.8g/kg diet (T_5).*

***The present results showed that** the final live body weight (LBW) of rabbit fed arginine by 1g/kg diet (T_3) was insignificantly higher (2500.0g) than the other groups (T_1, T_2, T_4 and T_5) being 2280.0; 2487.50; 2446.88 and 2316.43g, respectively. Also, T_3 group recorded significantly ($P<0.05$) the highest daily weight gain (DWG) compared with either those fed control and other experimental groups during the whole experimental period. Using of arginine by 1g/kg diet (T_3) recorded significantly ($P<0.05$) the highest daily feed consumption during 5-13 weeks compared to control and other experimental groups. Feed conversion ratio (FCR) was recorded insignificantly best value by using 1.2g/kg diet (T_4) at the end of experimental period. Results of EE digestibility showed significantly ($P<0.05$) improvements by increasing level of dietary Arg. in tested group T_4. NFE digestibility values achieved significantly ($P<0.05$) improvements in T_3 group followed by T_4, T_2, control group (T_1) and T_5 group. Rabbits fed diets containing dietary arginine by 1.2g/kg diet (T_4) were the best immunity compared with control and other experimental groups. T_5 group had significantly ($p<0.05$) the lowest abdominal fat% followed by T_4 group compared with control group (T_1) which the highest one. The highest value of performance index (PI) was insignificantly ($P>0.05$) recorded for T_4 and T_3 groups while, control group value achieved the worst one. From economical* *point of view, these findings indicated that rabbits fed diets containing arginine by 1g or 1.2g/kg diet had positive effects on economic parameters.*

***Conclusively**, based on the results obtained in this study, it was established that, containing dietary arginine by 1g or 1.2g/kg diet for growing rabbit's diets achieved improvements in growth performance parameters, digestibility coefficients, hematological and biochemical parameters; overall acceptability for organoleptic evaluation of cooked rabbit's meat, decreasing nitrogen of rabbit feces, and economic efficiency.*

Keywords: Arginine; economic efficiency; growing rabbits; immune response; performance.

Increased consumer awareness of food safety, as well as health safety, led to prevent the using of antibiotics as feed additives that acted as growth promoter by European Union (EU) in 2006 (Dawood *et al.*, 2018). Rabbits are highly efficient in producing meat compared to other farm animals. For this reason, rabbits can be considered a source of animal protein and could be subjected to local conditions (Candellone *et al.*, 2019). Over the past few years, many advances have been made in the nitrogen nutrition of rabbits. Arginine is an essential amino acid for its pharmacological and physiological characteristics, due to these capabilities; *Arg.* becomes hotspot and essential in researches of animal nutrition (Khajali and Wideman, 2010). Arginine has been reported to be an essential amino acid for optimal growth, maintenance and nitrogen balance in suckling pigs (Geng *et al.*, 2011). *Arg.* is antioxidant and anti-inflammatory and also reduces oxidative damage and tissue radiation. In addition, *Arg.* improves cellular function in young animals. In animal production, its application mainly focuses on poultry and pigs, and recently it has been used in researches of rabbits (Waseem *et al*., 2019). Jahanian (2009) found that the deficiency of arginine in the ration significantly reduced the spleen weight ($P<0.05$) and thymus ($P<0.01$) in the broiler, reducing antibodies titers against Newcastle disease and reduced in the proportion of heterophils in peripheral blood. Fouad *et al.* (2012) showed that adding *Arg.* can improve the level of immunity in broiler and increase coccidiosis resistance. *Arg.* application in animal nutrition still needs detail and more researches, not just from the *Arg.* synthesis process, it is also necessary to thoroughly study the functions of *Arg.* in poultry and different livestock and different stages of growth (Waseem *et al.*, 2019). However, there are many opportunities to broaden knowledge about amino acid metabolism in order to meet specific requirements to improve the health of rabbits (Carabaño *et al*., 2009).

Therefore, the objective of this research is to determine the effect of addition different levels of arginine on growth performance and some blood biochemical parameters, digestibility, immunity and carcass traits of growing NZW rabbits.

MATERIALS AND METHODS

The present experiment was conducted at Environmental Studies and Research Institute Farm belonging to University of Sadat City from January to February, 2018. The laboratory work was done at animal production and poultry laboratories of Environmental Studies &Research Institute and the Regional Center for Food and Feeds.

Forty growing NZW rabbits of both sexes (males and females), aged 5 weeks with an average initial weight of 739.2±13.15 g.

The experimental rabbits were randomly assigned 5 groups. Each group has 4 replicates. Each replicate consists of 2 rabbits. All rabbits were individually housed in galvanized wire cages (45 cm x 54 cm x 35 cm) with feeder and automatic nipple drinker and kept under the same managerial conditions. Formulated diets of 17% crude protein were used, the diet containing 17% CP (control or basal diet, T_1). The Experimental groups were arranged as the following:

Group 1: (T_1) (Control or basal diet) contain the requirements of arginine according to (NRC, 1977) (0.6g/ kg diet) - (basal diet)

Group 2: (T_2) Addition of arginine by 0.2 g/kg diet to the basal diet (0.8 g/kg diet)

Group 3: (T_3) Addition of arginine by 0.4 g/kg diet to the basal diet (1.0 g/kg diet)

Group 4: (T_4) Addition of arginine by 0.6 g/kg diet to the basal diet (1.2 g/kg diet)

Group 5: (T_5) Addition of arginine by 0.8 g/kg diet to the basal diet (1.4 g/kg diet)

In order to determine the growth performance, some blood biochemical parameters, digestibility and carcass traits of growing NZW rabbits were measured for two months. All rabbits remained under the same marginal conditions. Feed and water were offered *ad libitum* throughout the experimental period (8 weeks).

The composition of the feed ingredient for control diet is presented in Table 1. Rabbits were weighed individually at the end of each week, during the whole experimental period of 8 weeks (from 5 to 13 weeks of age) to the nearest gram. Live performance measurements for each feeding period were measured and / or calculated in terms of live body weight (LBW, g) and body weight gain (BWG, g), which was calculated by subtracting the average body weight from the average final body weight of the rabbit.

Feed intake for each replicate was weekly calculated, on a group basis,

Table 1. Composition of ingredient feed rations for control and treated groups.

Ingredients	**Basal diet (Control group)**
Clover Hay	25
Wheat bran	26
Barley grains, ground	20
Soybean meal (44% CP)	13.5
Yellow corn, ground	10.00
Wheat straw	1.50
DL-Methionine	0.35
Premix*	0.50
Na Cl	0.35
Di calcium phosphate	1.90
$CaCO_3$	0.90
Total (kg)	**100**
Calculating chemical Analysis	
Crude protein %	17.24
De, kcal/kg diet	2520
Crude fiber %	12.00
Ether extract %	2.59
Calcium %	1.1
Available phosphorus (mg/100g)	0.41
Lysine %	0.81
Methionine (mg/100g)	0.60
Cost/kg of diet in L.E.	4.0

Each one kg of vitamin & mineral mixture contains: Vit.A 4000000 IU; Vit D3 50000IU; Vit E 16.7g.; Vit K3, 0.67g.; Vit.B1 67g; VitB2 2.00g; Vit. B6 0.67g; Vit B12 3.33mg ; Choline chloride 400g.; Biotin 0.07g ;Niacin 16.7g.; pantothenic acid 6.7g; Folic acid 1.7g;; Copper 1.7g; Iron 25.00g; Manganese 10.00g; Iodine 0.25g; Selenium 33.3g; Zinc 23.3g and Magnesium 133.3g.

According. To NRC (1977) and Feed Composition Tables for animal & poultry feedstuffs used in Egypt (2001).

The prepared diets were iso- nitrogenous, iso- caloric and had nearly equal level of CF.

DE (Kcal/kg) = 4.36-0.0491xNDF%& NDF%=28.924+0.657xCF%. According to (Cheeke, 1987). According to market prices of the year 2018 .

by subtracting the residual feed from the offered one. Average daily feed intake per rabbit was then calculated by using the following equations:

$$\text{FI/rabbit/day} = \frac{\text{FI / replicate/week}}{\text{No. of rabbits consumed feed daily during the week period}}$$

Average daily feed intake (FI) per rabbit was calculated at the end of every week as follows:

FI = Total feed intake in gram per day per group / Number of rabbits.

Feed conversion ratio (FCR) weekly and whole experimental period was calculated for each replicate under each treatment and calculated as kg of feed used for producing one kg of body weight gain as follows:

FCR =Average feed intake (kg) per rabbit / body weight gain (kg) per rabbit.

The performance index (PI) weekly and the whole experimental period, was calculated for each replicate under each treatment according the equation according to North and Bell (1981) as follows:

PI (%) = LBW (kg)/ FCR x100

Weekly mortality rate was calculated for each treatment group by subtracting the final number of live rabbits at the end of a certain period from the initial number of live rabbits at the beginning of the same period. Mortality rate percentage was calculated as a number of dead rabbits at the end of a certain period relative to the initial number of live rabbits at the onset of the same period.

$$\text{Mortality \%} = ((N_1\text{-}N_2/N_1) \times 100)$$

Where, (N_1)**:** Number of rabbits at the start of experiment and **(N_2):** Number of the live rabbits at the end of 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), ether extract (EE), nitrogen free extract (NFE), digestible crude protein (DCP%). 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 lasted for 10 days as preliminary period while the collection period lasted for 5 days in which 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 $^{\circ}$C for 24 hrs. in an air drying oven. The feces were then ground and mixed, stored for subsequent chemical analysis (Aml Abd-Elsalam,1998). Feed and feces samples were chemically analyzed to determine the digestibility coefficients and nutritive values of the experimental diets.

Amino acids

Performic acid oxidation is performed prior to hydrolysis to oxidize cysteine and methionine to cystic acid and methionine sulfide. Hydrolysis was carried out in closed conical flask for determining all amino acids. Sample equal to 10 mg of protein was weighed in the conical flask and 5 ml of performic acid was added. The flask was closed and placed in ice bath for 16 hrs. Sodium disulfide and 25 ml HCL 6N was added to the oxidized mixture. The flask was placed in an oven at 110 C^{o} for 24 hrs. The flask was then opened using rotary evaporator to reduce the volume 5-10 ml under vacuum at 60 C°. Adjust the pH to 2.20 with sodium hydroxide solution. Suitable volume of sodium citrate buffer (pH 2.20) was added, to hydrolyzed sample. After all soluble material completely, dissolved, the sample is ready for analysis (AOAC, 2012). The system used for the analysis was high performance amino acid analyzer (Biochrom 30).

Chemical analysis

The proximate chemical analysis of experimental diets and dried feces for moisture, dry matter (DM), organic matter (OM), crude protein (CP), ether extract (EE) and Ash was carried out according to the Association of Official Analytical Chemists (AOAC., 2000). Nitrogen free extract (NFE) of both feed and feces was determined using the following equation:

$$NFE = 100 – (CP\% + EE\% + CF\% + Ash\ \%).$$

Blood parameters

Blood samples were collected from each rabbit (3 rabbits /group) into dry clean tubes containing heparin and centrifuged at 3000 rpm for 15 min. The plasma was collected and stored at -20˚C to estimate some blood constituents as total protein (Armstrong and Corri, 1960), albumin (Doumas *et al.*, 1971), transaminase (aspartate aminotransferase (AST) and alanine aminotransferase (ALT)) (Reitman and Frankel, 1957), triglycerides (Royer and Ko, 1969), cholesterol (Zlatkis *et al.*, 1953), urea nitrogen and creatinine. The globulin values were obtained by subtracting the albumin values from the corresponding values of total proteins.

Carcass traits

At the end of trial (13 weeks of age), 15 rabbits (3 rabbits/treatment) were slaughtered according to the standard technique of Cheeke (1987). After complete bleeding, skinning, and removing of viscera, weight of hot carcass was determined. Weights of internal organs including liver, kidney, spleen, heart, lung, pancreas, abdominal fat, full stomach, full intestine, caecum and thyroid were also determined, and their relative weights to the live body weight were calculated.

At the end of the 1st feeding trial, sensory evaluation was carried out to evaluate the color, odor, taste, texture and overall acceptability by boiling the carcass (3 rabbits/treatment) individually for minutes in water without addition of any flavor enhancer.

Organoleptic evaluation of cooked rabbit's meat

At the end of feeding trial, sensory evaluation was carried out to evaluate the color, odor, taste, texture and overall acceptability by boiling the carcass (3 rabbits/treatment) individually for minutes in water without addition of any flavor enhancer. Overall acceptability of all samples was carried out using ten point standardized numerical scale, where ten corresponded to 'components characteristic of the highest quality'. Scores from 6-10 were considered acceptable. The panel consisted of 9 experienced members of the staff who were familiar with meat characteristics. The descriptions of sensory properties were on the evaluation form of Kanatt *et al.* (2010).

Economic efficiency

Economic efficiency was calculated by the following equation:
Economic efficiency = (Selling price of one Kg live body weight - feeding cost of one Kg live body weight/ Feeding cost of one Kg live body weight) × 100

Statistical analysis

Data collected in this study were statistically analyzed using the general linear models (GLM) of **SAS (2002)**. One way analysis of variance (ANOVA) was used to study the effect of treatment on different parameters, the used model was:

$$\mathbf{Y_{ij} = \mu + T_i + e_{ij}}$$

Where, Y_{ij}= the observation of the parameter measured, μ = Population mean, T_i = amino acid arginine levels, e_{ij} = is the residual assuming to be NID $(0,\sigma^2 e)$.

Significant differences among means were achieved using the Duncan's of multiple range test **(Duncan, 1955).** Significant level was set at 5%.

RESULTS AND DISCUSSION

Data presented in Table 2 showed the proximate analysis of the basal diet. The basal diet was formulated to maintain a suitable supply of all nutrients recommended by De Blas and Mateos (1998) for growing rabbits and experiments researching the optimal starter feed composition (Chamorro *et al.,* 2007).

Table 2. Chemical composition (Proximate Analysis) of experimental rations (as fed).

Items	DM %	Moisture %	OM %	CP %	CF %	EE %	NFE %	Ash %	DE *(Mcal/kg)**
Ration	89.27	10.73	80.82	16.94	10.94	2.65	50.29	8.45	2.59

*DE *(Mcal/kg)* = 4.36 – 0.049 x NDF, NDF% = 28.924 +0.657 (CF %) according to Cheek (1987).

Amino acids composition of the experimental diets

Amino acids compositions of the control diet are presented in Table 3. All diets have the same level of amino acids, with the exception of arginine which is more than control in other experimental treatments because of its addition in different proportions.

Table 3. Amino acids composition of control diet (g/kg DM).

Amino Acids	**T_1 (0.6g/kg)**
Aspartic acid	1.62
Threonine	0.67
Serine	0.76
Glutamic acid	2.71
Glycine	0.82
Alanine	1.17
Valine	0.77
Iso Leucine	0.66
Leucine	1.3
Tyrosine	0.47
Phenylalanine	0.76
Histidine	0.4
Lysine	0.76
Arginine	0.61
Proline	1.25
Cysteine	0.4
Methionine	0.58
Total	**15.71**

Productive performance

Results in Table 4 showed that using of arginine by 1g/kg diet (T_3) recorded significantly ($P<0.05$) the best body weight value (1766.87 g), meanwhile, the lowest body weight was achieved with control group (T_1) being 1550.63 g at 9 weeks of age. The same trend was observed at 13 weeks of age with no significant difference ($P>0.05$). Also, rabbits fed arginine by 1g/kg diet (T_3) recorded significantly ($P>0.05$) highest DWG compared with either those fed control and other experimental groups during the whole experimental period. Also, Table 4 presented that using of arginine by 1g/kg diet (T_3) recorded significantly ($P<0.05$) the highest daily feed consumption during 5-13 weeks compared to control and other groups. The best non-significant value of the feed conversion ratio (3.28) was recorded using 1.2g/kg diet (T_4) at the end of the experiment period. Improvement of feed conversion and daily weight gain in rabbits fed arginine by 0.8g/kg (T_2), 1g/kg diet (T_3) and 1.2g/kg diet (T_4) may be due to its highly level of arginine in the diets. These results were in close agreement to the findings obtained by Delgado *et al*. (2019), who reported that in the whole period, treatments did not affect the feed intake, weight gain, final body weight and feed efficiency. Also, they found that rabbits that fed with *Arg.* or *Gln.* diets had a higher body weight at weaning by

Table 4. Effect of feeding different levels of arginine (Means ± SE) on productive performance of growing rabbits.

Item	Treatments					±SE	Sig.
	T_1	**T_2**	**T_3**	**T_4**	**T_5**		
No. of rabbits	8	8	8	8	8		
			Live body weight (g)				
5 weeks	733.13	746.88	741.88	731.25	745.63	30.95	NS
9 weeks	1550.63^{b}	1709.38^{ab}	1766.87^{a}	1726.88^{ab}	1663.13^{ab}	57.91	*
13 weeks	2280.0	2487.50	2500.0	2446.87	2316.43	72.74	NS
			Daily weight gain (g)				
5-9 weeks	29.20	34.38	36.61	35.56	32.77	2.01	NS
9-13 weeks	24.39	27.79	26.18	25.71	21.93	1.42	NS
5-13weeks	26.79^{c}	31.08^{ab}	31.40^{a}	30.64^{ab}	27.35^{bc}	1.26	*
			Daily feed consumption (g)				
5-9weeks	80.63^{b}	94.20^{a}	93.66^{a}	89.38^{a}	86.25^{ab}	2.87	*
9-13weeks	114.91	113.26	119.46	109.33	114.02	3.27	NS
5-13 weeks	97.77^{b}	103.73^{ab}	106.56^{a}	99.35^{b}	100.13^{b}	2.09	*
			Feed conversion ratio (g feed/ g gain)				
5-9 weeks	2.92	2.76	2.58	2.59	2.69	0.18	NS
9-13 weeks	4.78^{ab}	4.09^{b}	4.78^{ab}	4.30^{b}	5.27^{a}	0.25	*
5-13 weeks	3.70	3.35	3.45	3.28	3.70	0.15	NS
			Survival rate (%)				
5-13 weeks	**100**	**100**	**100**	**100**	**100**		

a, b, c Means within the same raw with different superscripts, differ significantly (P>0.05)
Sig. = Significance; NS = Not significant, * =(P>0.05)
SE= Standard error,T_1= Control diet (0.6g arginine/kg diet); T_2 = Addition of arginine by 0.8g/kg diet; T_3 = Addition of arginine by 1.0g/kg diet, T_4 = Addition of arginine by 1.2g/kg diet, T_5= Addition of arginine by 1.4g/kg diet.

9 and 5%, respectively than those from litters of rabbit fed with *Arg. + Gln.* and Vit. B diets. Supplementation with *Arg.; Gln.* or *Arg.+ Gln.* did not affected growth performance because the levels of amino acid were enough to meet requirements of rabbits post-weaning (Baylos *et al.,* 2008; Chamorro *et al.,* 2010). Also, Delgado *et al.* (2017) reported that supplementation of *Arg.* or Gln. had a positive effect on the weight of litters at weaning and litter size at birth. No mortality was recorded during the experimental period in rabbits groups fed diet containing any of the experimental diets. The results of mortality rate may indicate that all animals were in good health and the dietary treatments had no adverse effect of any kind. These findings are in agreement with those of Zhou *et al*. (2012) who pointed that there was no mortality was obtained in fish fed with the experimental diets by the dietary arginine levels. These results were agreement with Jankowski *et al*. (2020) who found that higher dietary levels of *Met.* (45 vs. 30% of *Lys.* content) and *Arg.* (100 and 110 vs. 90% of *Lys* content)

have a more beneficial effect on the growth performance and immune status of turkeys.

Digestible nutrients, Nutritive values and nitrogen balance

Digestibility coefficients of nutrients, nutritive values and nitrogen balance are presented in Table 5. Results indicated a significant differences ($P<0.05$) among DM, OM, CP and CF digestibility for all treatments. Meanwhile, DM, OM and CP digestibility for T_5 (1.4g/kg) were the worst ones; being 69.93, 69.53, 70.63 and 35.53, respectively compared to control group and other experimental groups.

Results of EE digestibility showed significantly ($P<0.05$) improvements by increasing level of dietary Arg. in tested group T_4 being 62.17%. While, group fed diet supplemented 1g dietary arginine/kg (T_3) and 1.4g dietary arginine /kg (T_5) showed the worst values (56.56 and 56.56%) compared with control group (58.3%) and T_2 group (57.00%).

NFE digestibility values achieved significantly ($P<0.05$) improvements in T_3 group followed by T_4, T_2, control group (T_1) and T_5 (82.03, 81.37, 80.10, 79.63 and 76.60, respectively).

Results also, indicated that values of digestible CP significantly ($P<0.05$) recorded the highest value with T_4 group (15.2) followed by T_2 (15.13) while, T_3 group was the worst one (13.8). Carabaño *et al.* (2008) stated that digestible protein (DP) to digestible energy (DE) ratio is a more reliable unit as it has a higher and direct effect on the nitrogen of body and energy retention than the fiber content in the diet, which is inversely related with digestible energy. So, the optimal level for crude protein in a diet depends on its digestibility and the DE content.

TDN significantly ($P<0.05$) achieved the highest value with T_4 group (68.9) followed by T_3 and T_2 (68.53 and 68.15) while, T_5 group was the worst one (63.84).This increase may be due to the significantly improvement in digestion coefficient of most nutrients. It also, could be due to the improvement of nutrients quality, besides increasing protein, vitamins and minerals content during vegetation process (Dung *et al*., 2010).

Concerning of nitrogen retention (nitrogen balance) (NB), results showed that the highest value of NB significantly ($P<0.05$) recorded by group containing 1.2 g/ kg dietary arginine (T_4) (2.22). Meanwhile T_5 group detected significantly ($P<0.05$) the worst one (1.54) compared with control group and other experimental groups.

Carabaño *et al*. (2000) suggested that fecal balance is not correct for characterizing the absorption of amino acids at ileal level and consequently for meeting the amino acid requirements. Consequently, studies have recently been carried out to characterize the digestible amino acid content in the main raw materials used in rabbit diets.

Table 5. Effect of feeding different levels of arginine (Means ± SE) on digestibility Coefficient, nutritive values and nitrogen balance of growing rabbits.

Items	Treatments					Sig.
	T1 (Control)	T_2	T_3	T_4	T_5	
Nutrients digestibility coefficients (%)						
DM	74.51[a] ±0.69	72.77[a] ±0.69	74.24[a] ±0.69	74.41[a] ±0.69	69.93[b] ±0.69	*
OM	74.03[a] ±1.14	74.10[a] ±1.70	74.33[a] ±0.91	74.37[a] ±0.48	69.53[b] ±0.48	*
CP	78.46[a] ±0.92	78.53[a] ±1.79	75.13[a] ±0.96	77.13[a] ±0.80	70.63 [b] ±0.23	*
CF	45.07[a] ±2.28	41.16[ab] ±1.44	37.33 [b] ±2.24	38.80 [b] ±0.21	35.53 [b] ±1.66	*
EE	58.30[ab] ±1.71	57.00[b] ±1.31	56.56 [b] ±1.79	62.17[a] ±1.65	56.56[b] ±1.20	*
NFE	79.63[a] ±0.80	80.10[a] ±1.80	82.03[a] ±0.58	81.37[a] ±0.32	76.60[b] ±0.31	*
Nutritive values (%)						
DCP	14.9[a] ±0.19	15.13[a] ±0.19	13.8[b] ±0.19	15.2[a] ±0.19	14.1[b] ±0.19	*
TDN	67.4 [a] ±0.93	68.15[a] ±0.93	68.53[a] ±0.93	68.9[a] ±0.93	63.84[b] ±0.93	*
Nitrogen Balance						
NB	2.18[a] ±0.04	2.16 [a] ±0.04	2.0[b] ±0.04	2.22[a] ±0.04	1.54[c] ±0.04	*

a, b, c Means within the same raw with different superscripts differ significantly P>0.05),
Sig. = Significance, NS = Not significant, * =(P>0.05) SE= Standard error,
T_1= Control diet (0.6g arginine/kg diet); T_2 = Addition of arginine by 0.8g/kg diet; T_3 = Addition of arginine by 1.0g/kg diet, T_4 = Addition of arginine by 1.2g/kg diet, T_5= Addition of arginine by 1.4g/kg diet. OM: Organic matter; DCP: Digestible crude protein; DCF: Digestible crude fiber; DEE: Digestible ether extract; DNFE: Digestible nitrogen free extract.

Blood constituents

Blood plasma biochemical analysis values are used as indicators of the health status of rabbits. Some blood constituents as immune response indicator of experimental rabbits as affected by different levels of dietary arginine are presented in Table 6.

The total plasma proteins (TP) are considered mainly to contain plasma albums (A) and plasma globulin (G). The TP is an important factor for acid-base balance, blood viscosity and supplying necessary enzymes.

Results showed that rabbits received dietary arginine by 1.2g/kg diet (T_4) recorded significantly (P<0.05) higher value of TP (g/dl); Albumin (Alb) (g/dl)

Table 6. Effect of feeding different levels of arginine (Means ± SE) on blood parameters of growing Rabbits**.**

Items	**Treatments**					**Sig.**
	T_1	**T_2**	**T_3**	**T_4**	**T_5**	
TP(g/dl)	7.3^{c} ±0.04	6.6^{d} ±0.04	5.8^{e} ±0.04	8.1^{a} ±0.04	7.5^{b} ± 0.04	*
Alb.(g/dl)	3.8^{b} ±0.04	3.63^{c} ±0.04	3.8^{b} ±0.04	4.4^{a} ±0.04	4.4^{a} ±0.04	*
Glob.(g/dl)	3.5^{a} ±0.08	3.0^{b} ±0.08	2.1^{c} ±0.08	3.7^{a} ±0.08	3.1^{b} ±0.08	*
A/G ratio	1.1^{c} ±0.07	1.2^{bc} ±0.07	1.9^{a} ±0.07	1.2^{bc} ±0.07	1.4^{b} ±0.07	*
Chol. (mg/dl)	32.27^{c} ±1.73	59.0^{a} ±1.73	45.0^{b} ±1.73	34.33^{c} ± 1.73	41.0^{b} ±1.73	*
Creat.(mg/dl)	0.7^{b} ±0.04	1.2^{a} ±0.04	1.3^{a} ±0.04	0.8^{b} ±0.04	1.2^{a} ±0.04	*
Urea(mg/dl)	18.0^{b} ± 0.6	18.0^{b} ±0.6	20.0^{a} ± 0.6	18.0^{b} ± 0.6	20.0^{a} ± 0.6	*
Alk. Ph(U/L)	418.7^{bc} ±1.2	420.33^{b} ±1.2	427.33^{a} ±1.2	416.0^{c} ± 1.2	424.33^{a} ±1.2	*
AST (U/L)	21.0^{a} ±1.2	15.33^{c} ±1.2	17.0^{bc} ±1.2	14.0^{c} ±1.2	20.0^{ab} ±1.2	*
ALT(U/L)	17.7^{b} ± 1.23	17.0^{b} ±1.23	24.33^{a} ±1.23	13.0^{c} ±1.23	20.0^{b} ± 1.23	*

a, b, c Means within the same raw with different superscripts differ significantly P>0.05), **T_1**=Control diet (0.6g arginine/kg diet);**T_2** = Addition of arginine by 0.8g/kg diet; **T_3** = Addition of arginine by 1.0g/kg diet, **T_4** = Addition of arginine by 1.2g/kg diet, **T_5**= Addition of arginine by 1.4g/kg diet. TP (g/dl): Blood total protein; Alb.(g/dl): Blood albumin ;Glob.(mg/dl):Blood globulin and A/G: Albumin : Globulin ratio.

and (Glob) (mg/dl) (8.1 g/dl, 4.4g/dl and 3.7mg/dl, respectively) compared to control group and other experimental group. While, rabbits group received dietary arginine by 1.0g/kg diet (T_3) recorded significantly higher value of A/G ratio (1.9).

Based on these results, it can be reported that rabbits fed on diets with supplementation of dietary arginine by 1.2g/kg diet (T_4) were the best immunity compared with those of control and other experimental rabbits groups. These results are in agreement with those obtained by Birmani *et al*. (2019) who 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).

Also, results of Table 6 indicated that group supplemented with arginine by 0.6 g/kg diet (T_4) recorded significantly (P<0.05) the lowest values of total cholesterol (34.33mg/dl); creatinine (0.8 mg/dl); Urea (18.0 mg/dl); alkaline pH. (416.0U/L); AST (14.0 U/L) and ALT (13.0U/L). These values were in the range of normal values defined for these parameters by previous studies **(**Silva *et al.*, 2005; Elmas *et al.*, 2006 and Melillo, 2007) in growing rabbits. Meanwhile, group supplemented of arginine by 0.8g/kg diet (T_5) were significantly (P<0.05) the highest one among values of urea (20.0 mg/dl); alkaline pH. (424.33U/L); AST (20.0 U/L) and ALT (20.0U/L) compared with control diet and other experimental groups. While group fed diet containing arginine by 0.8g/kg diet (T2) were significantly (P<0.05) the highest one among values of plasma cholesterol (59 mg/dl). For plasma creatinine, group fed diet containing arginine by 1g/kg diet (T3) presents significantly (P<0.05) the highest one (1.3mg/dl). Jankowski *et al.* (2020) concluded that the higher dietary Met. level (45 vs. 30% of *Lys.* content) increased the final BW of turkeys and caused beneficial increased plasma albumin concentration. Also they stated that different dietary *Arg.* levels had no influence on the growth performance of turkeys. However, in younger birds (1–8 weeks of age), the lowest *Arg.* level (90% of *Lys.* content) decreased BW and dressing yield at the end of rearing and weakened the immune function of turkeys by decreasing globulin concentration and increasing the concentration of the prion flammatory cytokine IL-6 in their blood plasma.

Carcass characteristics

The slaughter parameters as affected by different levels of dietary arginine are presented in Table 7. Results indicated that the heaviest pre-slaughter weight was recorded for T_3 group (2521.7g) while, the lowest pre-slaughter weight significantly (P<0.05) recorded for T_5 group (2231.67 g). Also, the significantly highest value of carcass weight was recorded with T_2 group followed by T_3 group (1483.33g and 1401.7g, respectively) and the lowest one was noticed by T_5 group (1301.7g). Significant differences (P<0.05) were recorded between the experimental groups regarding dressing % and the best dressing % value (59.6%) was noticed with control group (T_1) and did not significantly (P<0.05) differ from T_2 (59.01%); T_4 (57.10%) and T_5 (58.31%). While group contain 1g dietary arginine /kg (T3) achieved the lowest one (55.60%). For abdominal fat% as a percentage of live body weight, it was noticed that T_5 had significantly (P<0.05) the lowest value (0.89%) followed by T_4 (1.04%) while, the highest value of abdominal fat was recorded with control group (T_1) (2.17%); T_3 (2.03%) and T_2 (1.94%). These results are in agreement with the findings obtained by Namera *et al.* (2011). Regarding the results of liver weight (%) as a percentage of LBW, results in Table 7 indicated that group containing 0.8g arginine/kg diet (T_2) significantly (P<0.05) recorded

Table 7. Carcass characteristics of experimental rabbits (Means ± SE) as affected by different levels of dietary arginine.

Items	Treatments					Sig.
	T_1 Control (0.6g/kg)	**T_2 (0.8g/kg)**	**T_3 (1.0g/kg)**	**T_4 (1.2g/kg)**	**T_5 (1.4g/kg)**	
LBW	2235.0^{b} ±36.63	2513.3^{a} ± 36.63	2521.7^{a} ± 36.63	2410.0^{a} ±36.63	2231.67^{b} ±36.63	*
Carcass wt.(g)	1331.7^{b} ±35.74	1483.33^{a} ±35.74	1401.7^{ab} ±35.74	1376^{ab} ±35.74	1301.7^{b} ± 35.74	*
Dressing%	59.6^{a} ±0.9	59.01^{a} ±0.9	55.6^{b} ±0.9	57.1^{ab} ± 0.9	58.31^{ab} ±0.9	*
Abdominal Fat%	2.17^{a} ±0.29	1.94^{a} ±0.15	2.03^{a} ±0.38	1.04^{b} ±0.13	0.89^{b} ±0.32	*
Liver Weight%	3.18^{bc} ±0.01	3.69^{a} ±0.09	2.84^{cd} ±0.01	2.69^{d} ±0.02	3.28^{ab} ±0.02	*
Spleen%	0.05^{ab} ±0.01	0.04^{b} ± 0.001	0.07^{a} ±0.01	0.06^{ab} ± 0.01	0.08^{a} ±0.001	*

a, b, c Means within the same raw with different superscripts differ significantly P>0.05), T_1=Control diet (0.6g arginine/kg diet); T_2 = Addition of arginine by 0.8g/kg diet; T_3 = Addition of arginine by 1.0g/kg diet, T_4 = Addition of arginine by 1.2g/kg diet, T_5= Addition of arginine by 1.4g/kg diet. *LBW: Live body Weight; Carcass wt.(g): Carcass weight(g); D%: Dressing %; AF: Abdominal fat (%); LW:Liver weight.

the highest liver percentage (3.69%), while, T_4 detected the lowest liver percentage (2.69%) as compared with control and other experimental groups. Also, Results of Spleen % showed significant differences (P<0.05) among experimental groups except T_2 which was significantly the lowest percentage (0.04%) compared to T_3 and T_5 groups. Oso *et al.* (2017) found that arginine supplementation enhanced the relative weights of thymus, spleen, and reduced Salmonella counts in small intestine of turkeys. These results are consistent with Jankowski *et al.* (2020) who found that the highest Arg. Level (110% of the Lys content) had a beneficial effect by increasing the proportion of breast muscles in the final body weight of the turkey.

Organoleptic evaluation of cooked rabbit's meat

Organoleptic evaluation values of cooked meat in terms of color, odor, taste, and overall acceptance are presented in Table 8. Results cleared that there were significant effects (P<0.05) in organoleptic evaluation parameters (Color; taste; and overall acceptability) in all experimental groups. Whereas, group fed dietary arginine (T_4) significantly (P<0.05) recorded the best color**;** taste; and overall acceptability compared with control and other experimental diets. While, for odor, T_4 recorded insignificantly highest value compared to control and other experimental groups. Meanwhile group fed control diet (T_1) significantly (P<0.05) achieved the worst overall acceptability.

Table 8. Organoleptic evaluation (Sensory) of cooked rabbit's meat (Means ± SE) as affected by different levels of arginine.

Items	Treatments					Sig.
	T_1 Control (0.6g/kg)	**T_2 (0.8g/kg)**	**T_3 (1.0g/kg)**	**T_4 (1.2g/kg)**	**T_5 (1.4g/kg)**	
Color	8.3^{b} ±0.39	8.3^{b} ±0.39	8.0^{b} ±0.39	9.7^{a} ±0.39	8.3^{b} ±0.39	*
Odor	7.7 ±0.42	8.0 ±0.42	8.0 ±0.42	9.0 ±0.42	8.3 ±0.42	NS
Taste	8.0^{b} ±0.26	8.3^{b} ±0.26	8.7^{ab} ±0.26	9.3^{a} ±0.26	8.0^{b} ±0.26	*
Overall acceptance	8.0^{b} ±0.19	8.2^{b} ±0.19	8.2^{b} ±0.19	9.3^{a} ±0.19	8.2^{b} ±0.19	*

a, b, c Means within the same raw with different superscripts differ significantly (P>0.05),
. * = P < 0.05, NS = Not significant SE= Standard error,
T_1=Control diet (0.6g arginine/kg diet);**T_2** = Addition of arginine by 0.8g/kg diet; **T_3** = Addition of arginine by 1.0g/kg diet, **T_4** = Addition of arginine by 1.2g/kg diet, **T_5**= Addition of arginine by 1.4g/kg diet.

Economic efficiency

One of the main aims of the present study was to detect the optimal percentage of dietary arginine supplementation to get the best economical efficiency for growing rabbits. Economic parameters of the present experimental diets are presented in Table 9. It should be pointed out that the calculation herein depended on the average price at 2017 (during which the experiment was executed). Generally, among the most important factors involved in the achievement of maximum efficiency in meat production are feeding cost, length of growing period and the final body weight.

Accordingly, the economic efficiency of any product could be calculated from input - output analysis based mainly up on the total feeding cost per total number of Kg LBW sold and the current selling price of LBW per kg (Hala, 1998).

Results showed an improvement in the average values of economical efficiency and relative economical efficiency due to feeding growing rabbits on the diets contain dietary arginine by 1.2g/kg diet (T4). While for total revenue and net revenue, growing rabbits fed on the diets containing dietary arginine by 1g/kg diet (T3) (96.8 and 72.32) was economically better than control diet (85.25%, 63.33, respectively), Meanwhile growing rabbits group fed dietary arginine by 1.4g/kg diet (T5) achieved the lowest average values of net revenue, economical efficiency and relative economical efficiency (62.24; 2.64and 91.35%).

Table 9. Economical efficiency of growing rabbits as affected by supplemented dietary different levels of arginine.

Items	Tested diets				
	T_1 Control (0.6g/kg)	**T_2 (0.8g/kg)**	**T_3 (1.0g/kg)**	**T_4 (1.2g/kg)**	**T_5 (1.4g/kg)**
Av. feed intake (Kg/rabbit), a	5.48	5.81	5.97	5.56	5.61
Price/ Kg feed (PT), b	4.00	4.05	4.10	4.15	4.20
Total feed cost (LE), a x b = c	21.92	23.53	24.48	23.07	23.56
Av. Body weight gain (Kg/rabbit), d	1.55	1.74	1.76	1.72	1.57
Price/Kg live body weight (LE), e	55	55	55	55	55
Total revenue (LE), (d x e = f)	85.25	95.70	96.80	94.60	85.80
Net revenue (LE), (f-c=g)	63.33	72.17	72.32	71.53	62.24
Economic efficiency, (g/c)	2.89	3.07	2.95	3.10	2.64
Relative economic efficiency	100	106.23	102.07	107.27	91.35
Performance index	47.44 ±3.4	53.47 ±3.4	54.04 ±3.4	55.72 ±3.4	49.005 ±3.4

According to the price of different ingredients available in the market at the experimental time (2017).According to the local market price at the experimental period. Net revenue per unit Cost. Compared to the economical efficiency of the control group. **T_1**=Control diet (0.6g arginine/kg diet);**T_2** = Addition of arginine by 0.8g/kg diet; **T_3** = Addition of arginine by 1.0g/kg diet, **T_4** = Addition of arginine by 1.2g/kg diet, **T_5**= Addition of arginine by 1.4g/kg diet.

The results indicated that the highest value of PI was insignificantly (P>0.05) achieved by T4 and T3 (55.72 and 54.04%) while, the lowest value recorded by the control group (47.44). This increase may be due to the improvement of the feed conversion as well as higher live body weight of those groups led to an increase in PI values. These results are in agreement with Musa (2008); Ahmed (2010) who reported that NWZ growing rabbits fed mixture of medicinal plants recorded better value of PI than control group.

Conclusively, based on the results obtained in this study, it was established that, containing dietary arginine by 1g or 1.2g/kg diet for growing rabbit's diets achieved improvements in growth performance parameters, digestibility coefficients, hematological and biochemical parameters; overall acceptability for organoleptic evaluation of cooked rabbit's meat, decreasing nitrogen of rabbit feces, and economic efficiency.

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تأثير إستخدام مستويات مختلفة من الحامض الأمينى أرجينين على الآداء وجودة اللحوم فى الأرانب النامية

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**المعمل الإقليمى للأغذية والأعلاف – مركز البحوث الزراعية - وزارة الزراعة – الدقى – الجيزة – مصر.

أجريت الدراسة لتحديد أثر استخدام مستويات مختلفة من الحامض الأميني أرجينين على أداء النمو، المناعة، بعض القياسات البيوكيميائية، الهضم، صفات الذبيحة والكفاءة الاقتصادية فى الأرانب النيوزيلاندية البيضاء النامية (عدد 40 أرنب من كلا الجنسين) عند عمر 5 أسابيع بمتوسط وزن 739,75 جم ± 13.15. تم تقسيم الأرانب إلى 5 مجموعات. تم استخدام عليقة أساسية تحتوى على 17 ٪ بروتين خام وكانت المجموعات التجريبية على النحو التالي: مجموعة الكنترول (T_1) وتحتوي على نسبة الأرجينين وفقًا لـ (NRC 1977 ، 0,6 جم/كجم من العليقة) ؛ المجموعة (T_2) تم إضافة الارجينين بنسبة 0,2 جم / كجم من عليقة الكنترول (0,8 جرام / كجم من العليقة) ؛ المجموعة (T_3)

تم إضافة الأرجينين بنسبة 0,4 جم / كجم إلى عليقة الكنترول (1 جرام/كجم من العليقة) ؛ المجموعة (T_4) تم إضافة الأرجينين بنسبة 0,6 جم / كجم إلى عليقة الكنترول (1,2 جم/كجم من العليقة) والمجموعة (T_5) تم إضافة الأرجينين بنسبة 0,8 جم / كجم إلى عليقة الكنترول (1,4 جم/كجم من العليقة). واشتملت الدراسة تقدير القياسات التالية : أداء النمو؛ الاستجابة المناعية؛ الهضم؛ ميزان النيتروجين (NB)؛ قياسات الدم ؛ صفات الذبيحة والكفاءة الاقتصادية.

أوضحت النتائج أن وزن الجسم النهائي فى مجموعة الأرانب المغذاه على أرجينين بنسبة 1 جم/كجم عليقة (T_3) (2500 جم) كان أعلى من المجموعات الأخرى T_1 وT_2 و T_4وT_5 (2280,0؛ 2487,50؛ 2446,87 و 2316,43 جم على التوالي). أيضا سجلت المجموعة T_3 أعلى زيادة فى النمو اليومى بالمقارنة بمجموعة الكنترول و المجاميع التجريبية الأخرى فى خلال فترة التجربة الكلية. سجلت مجموعة الأرانب التى غذيت على أرجينين بنسبة 1 جم/كجم عليقة (T_3) أعلى معدل مأكول يومى طول فترة التجربة بالمقارنة بمجموعة الكنترول والمجموعات التجريبية الأخرى. بينما سجلت مجموعة الأرانب التى غذيت على أرجينين بنسبة 1.2 جم/كجم عليقة (T_4) أعلى كفاءة غذائية فى نهاية فترة التجربة. أظهرت النتائج وجود فروق معنوية فى هضم OM و CP وCF لكل من المجاميع التجريبية. أوضحت نتائج هضم الدهون تحسن معنوى بزيادة مستوى الأرجينين فى العليقة فى المجموعة التجريبية T_4. حققت قيم هضم الكربوهيدرات الذائبة أعلى تحسن معنوى فى المجموعة T_3 متبوعا بالمجموعة T_4، T_2 ومجموعة الكنترول والمجموعة التجريبية T_5 .سجلت المجموعة التي تغذت على الأرجينين بنسبة 1,2جرام/كجم من العليقة (T_4) أفضل مناعة بالمقارنة بمجموعة الكنترول والمجموعات التجريبية الأخرى.أيضا وجد أن أقل نسبة دهون في البطن سجلت فى المجموعة T_5 تليها المجموعة T_4 بينما سجلت أعلى نسبة دهون في البطن مع مجموعة الكنترول (T_1). وكانت أعلى قيمة فى PI الكلية للمجموعتين T_4 وT_3 بينما أسوأ قيمة حققتها مجموعة الكنترول (T_1). أشارت نتائج الكفاءه الاقتصادية إلى أن مجموعة الأرانب المغذاه على الأرجينين بنسبة 1 جم أو 1,2 جم/كجم من العليقة كان لها تأثير إيجابي على الكفاءه الاقتصادية.

التوصية : توصى الدراسة بضرورة أضافة الارجنين الى علائق الارانب النامية بنسبة 1-1.2 جم /كجم عليقة لتحسين مناعة الارانب ورفع الكفاءة الغذائية للعليقة وتحسين اداء النو والكفاءة الاقتصادية **.**

الكلمات الدالة: أرجينين. الأرانب النامية ، أداء الأرانب ؛ الاستجابة المناعية؛ الكفاءة الاقتصادية.