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EFFECT OF ARGININE SUPPLEMENTATION ON PRODUCTIVE PERFORMANCE, CARCASS TRAITS, HEMATOLOGY AND ECONOMIC EFFICIENCY OF BROILERS UNDER HEAT STRESS CONDITIONS

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Abstract

A total of 180 unsexed broiler chicks (Arbor Acres, 7 days old) were used to assess the effects of different levels of arginine (Arg) supplementation on growth performance, carcass, hematology response and economic efficiency of broiler under heat stress (HS). Broilers were wing banded and randomly divided into five treatment groups (six replicates of six birds in each, with an average 209g ± 2.63/bird) from 7 to 35 days of age. Each replicate was kept in battery brooders in wire cages (55×50×35 cm). Birds of the first group were served as the positive control group and fed the basal diet without any addition under normal conditions, while the other four groups were exposed to HS and fed a basal diet supplemented with 0, 0.5, 1.0 and 2g Arg/kg diet. All diets were formed to meet or exceed NRC nutrient recommendations. HS decreased final body weight (BW) and body weight gain (BWG) compared to the positive control group, respectively. Supplementation of different levels of Arg improved the BW, BWG and feed conversion ratio (FCR) compared to the negative control group. Chicks receiving Arg under HS had higher red blood cells (RBCs), heamoglobin (Hgb) and packed cell volume (PCV) compared to the positive control group. Supplementation of different levels of Arg to the broiler diets under HS significantly improved the relative weights of dressing, liver, spleen, bursa and thymus compared with the relative weight of the negative group and complete recovery of the relative weight compared with the positive control group. Supplementation with different levels of Arg duet significantly improved and recorded the best economic

efficiency (EE), relative economic efficiency (REE), lower meat production cost (MPC) and net profit margin (NPM) than the positive and negative control groups.

In conclusion, the present results indicated that under HS, supplementation of dietary Arg to broiler diets could be able to elevate the adverse effect of HS and improve the productive performance, carcass traits, hematology and economic efficiency.

Keywords, broiler performance, carcass, hematology and economic.

INTRODUCTION

The chicken sector is one of the most economical sources of animal protein and is accepted by the majority of people of all classes in Egypt. It is also significantly more effective than red meat in providing a cheap supply of protein to meet the needs of the Egyptian population **(FAOSTAT, 2008 and 2010)**. Due to production losses caused by the sensitivity of the birds, heat stress (HS) is one of the most significant and difficult problems for the production of poultry globally **(Nawab *et al.*, 2018)**. Due to the absence of sweat glands, poultry is more susceptible to HS than mammals.

Chronic heat stress may lead to adverse changes in behavior, immune function, nutrient utilization, feed intake and growth, poor feed conversion ratio, and mortality **(Attia *et al.*, 2018; Nawab *et al.*, 2018; Pender *et al.*, 2020; Wang *et al.*, 2021)**. HS can also affect an animal's health and cause damage to various organs **(Bao *et al.*, 2008)**, which can even result in sudden death (**Allakhverdiev *et al.*, 2008).** The fundamental husbandry approaches to prevent HS include providing adequate shelter, altering the environment, and using biological methods to decrease metabolic heat generation **(Abo Gabal, 2015**). Also, HS exposure causes oxidative damage, immunological dysfunction, and growth performance degradation (**Saleh *et al.*, 2019; 2021; Abo Ghanima *et al.*, 2020; Hafez and Shehata, 2021; Shehata *et al.*, 2021).**

Recent research showed that amino acid supplementation increased gastrointestinal health, which in turn improved broiler growth performance (**Laudadio *et al.*, 2012; Wijtten *et al.*, 2010).** Numerous studies have demonstrated that broiler performance can be improved by dietary arginine levels above those suggested by the National Research Council (NRC) in 1994. **(Fernandes *et al.*, 2009; Jahanian, 2009**). The functional amino acid arginine has a role in the control of critical metabolic processes required for immunity, development, and reproduction as well as serving as a building block for proteins and polypeptides (**Liu *et al.*, 2012; Wu *et al.*, 2012**). Arginine, as a nutritional additive, has a positive effect on promoting chickens' development when included in their diet **(Fernandes *et al.*, 2009; Jahanian, 2009; Youssef *et al.*, 2016**). Because chickens don't have a functioning urea cycle, unlike mammals, chickens cannot generate arginine on their own, so they must provide to fulfill their demands for protein synthesis and other processes (**Tamir and Ratner, 1963; Khajali and Wideman 2010).** The amount needed for the chicken to function has generated a great deal of attention because it varies greatly depending on the situation. The source of dietary protein, ambient temperature, and the age and genotype of the animals are all factors that affect the demand **(Khajali and Wideman, 2010; Brake *et al.*, 1998; Chamruspollert *et al.*, 2004**). Proline, ornithine, polyamines, glutamate, and glutamine are all precursors of arginine (**Khajali and Wideman, 2010**), which also serves as a substrate for the biosynthesis of numerous molecules including protein and nitric oxide, a powerful vasodilator that reduces the incidence and severity of pulmonary hypertension syndrome (**Wideman *et al.*, 1995; 1996**). **Atakisi *et al.* (2009**) indicated that the addition of L-Arg in poultry diets is required to avoid the harmful influences of excessive free radicals that are produced during normal metabolism, and to relieve the adverse effects of heat stress **(Attia *et al.,* 2011**).

The objectives of the present study were to assess the effects of a supplemental different level of Arginine on growth performance, hematological, carcass traits and economic efficiency of broiler under heat stress.

MATERIALS AND METHODS

The present study was carried out at the Poultry Research Unit at Al-Bostan, Department of Animal and Poultry Production, Faculty of Agriculture, Damanhour University from May to June 2019, and the chemical analysis was carried out in El-Sabahia Poultry Research

Station, Alexandria Governorate belonging to Animal Production Research Institute, Agriculture Research Center, Ministry of Agriculture. The scientific committee of the Animal and Poultry Production Department, Faculty of Agriculture, Damanhour University had approved the experiment.

All treatments and birds care procedures were approved by the Institutional Animal Care and Use Committee in AU-IACUC, Damanhour University, Egypt. Authors declare that the procedures imposed on the birds were carried out to meet the Directive 2010/63/EU of the European Parliament and of the Council of 22 September 2010 on the protection of animals and birds used for scientific purposes. The amino acid arginine powder was presented as a gift from Multi Vita Animal Nutrition Company, Cairo, Egypt.

Broiler and experimental design

A total of 180 unsexed seven days old of broiler chicks (Arbor Acres) were acquired from a commercial hatchery (Cairo Poultry Company). At 7 days of age, the wing-banded chicks were randomly divided and kept similar initial body weight with a mean body weight of 209g±2.63. Broiler chicks were divided into five experimental groups (treatments) with six replicates of six birds in each, in a straight-run experimental design for a 28-day feeding trial (from 7 to 35 days of age). Each replicate was kept in battery brooders in wire cages (55×50×35 cm length-width-height). Birds of the first treatment group served as thermoneutral and was fed the basal diet without any addition, while the 2nd was fed the basal diet without any supplementation and exposed to HS (the negative control). The 3rd, 4th and 5th groups were fed diets containing 0.5; 1.0 and 2g Arg/kg diet, respectively. All diets were formed to meet or exceed **NRC (1994)** nutrient recommendations of chickens for starter (7-21 days) and finisher (21-35 days) periods Table (1).

Birds' management

In the preliminary period (1-7 days of age), all chicks were raised in battery brooders in one house of environmental control under thermos-neutral conditions. A gas heater was utilized to supply the chickens with the heat needed for brooding, (ambient temperature reached 30-32°C during), in a semi-opened room and remained under the same managerial, hygienic and environmental conditions. Throughout the following weeks of the experimental period, the heat weekly decreased by 3ºC. During the 4th and the 5th week, the temperature was maintained at 22-24ºC. A similar light schedule to the commercial condition was used; 23h light from one until 7 days old, pursued by 20h light from 8 days of age to the end of the experiment at 35 days of age. The average minimum, maximum temperature degree as °C and relative humidity as a percentage during 21-35 days of age were 22 to 24.9°C and 53.2 to 64.5%, respectively in both the two chambers.

Table 1. Composition and calculated analyses of the experimental diets.

Ingredients	Starter diet, 1-21 d of age	Finisher diet, 22-35 d of age
Yellow corn, kg	490	550
Soybean meal 48% CP, kg	420	358
Di-calcium phosphate, kg	20	15
Limestone, kg	10	12.5
Na Cl, kg	3.0	3.0
Vitamin+ mineral premix[1], kg	3.0	3.0
Dl-Methionine, kg	2.5	2.5
L- Lysine, kg	1.5	2.0
Vegetable oil[2], kg	50	54
Total	**1000**	**1000**
Metabolic energy, kcal/kg diet	3035	3135
crude protein %	22.9	20.8
calcium%	0.95	0.91
Available P%	0.52	0.42
Methionine%	0.60	0.56
total sulfur amino acids%	0.96	0.91
Lysine%	1.37	1.26
Ether extra%	4.70	4.80
Crude fiber%	3.30	3.80
Ash%	5.50	5.20
Dry matter%	90.10	91.20

[1]Vit+Min mixture provides per kg of the diet: vitamin A (retinyl acetate) 24mg, vitamin E (dl-α-tocopheryl acetate) 20 mg, menadione 2.3 mg, Vitamin D_3 (cholecalciferol) 0.05mg, riboflavin 5.5mg, calcium pantothenate 12mg, nicotinic acid 50mg, choline chloride 600mg, vitamin B12 10µg, vitamin B6 3mg, thiamine 3mg, folic acid 1mg, d-biotin 0.50mg. Trace mineral (mg per kg of diet): Mn 80 Zn 60, Fe 35, Cu 8, Se 0.60. [2] A mixture of soybean oil, cotton seed oil and sunflower at

33.33% of each. ME, metabolic energy; CP, crude protein; Ca, calcium; TSAA, total sulfur amino acids.

During the period 21–23 and 28–30 days old, the chicks in one chamber were exposed to heat stress (34ºC and 70–75% relative humidity) for 4 hours a day (from 10.00 am –2.00 pm), and returned to normal house temperature afterward in which the average temperature and relative humidity were 24.9ºC and 66% RH, respectively.
All birds were fed the experimental diets, *ad libtium,* and given free access to fresh water.

Data and sample collection

Broiler chickens and feed were weighed as a pen weekly during the experimental period for performance evaluation. Growth performance parameters, including body weight (BW), BW gain (BWG) and feed intake (FI) were measured, and feed conversion ratio (FCR) corrected for mortality was calculated.

At the end of the experimental period, six chicks from each treatment (n=6/treatment) were randomly selected at 08:00-09:00 am and about 3 ml of blood was collected from the wing vein into vacautainer tubes containing K_3-EDTA (1 mg/mL). Non-coagulated blood shortly after the collection was used for estimating red blood cells count (RBCs), white blood cell counts (WBCs) and differential leucocyte (lymphocytes (L), monocytes, heterophils (H), basophils and eosinophils), according to (**Feldman *et al.*, 2000**). Hemoglobin (Hgb) concentration and the percentage of packed cell volume (PCV %) were measured according to **(Drew *et al.*, 2004 and Hepler, 1966**). Heterophils to lymphocytes ratio (H/L) was calculated by dividing the total count of heterophils by the total number of lymphocytes.

Digestibility coefficients

Digestibility coefficients of nutrients of all experimental diets were obtained using five male birds at 35 wk of age from each treatment. Fecal nitrogen was determined following the procedure outlined by **Jakobsen *et al.* (1960).** The proximate analysis of feeds and excreta was carried out according to **AOAC (1995)**. Digestion coefficients of nutrients were calculated according to **Fraps (1946).**

Carcass characteristics

At d 35 of age, six broiler chicks from each treatment (one per each replicate) with equal numbers of each sex, were randomly selected for slaughtering with body weight similar to each treatment mean to determine carcass characteristics **(Blasco and Ouhayoun, 1996)**. The dressing and empty carcass and organs (liver, pancreas, abdominal fat, small intestine, spleen, bursa and thymus) were separately weighed and each of them was proportioned to the live pre-slaughtering weights (**Attia *et al.*, 2012**).

Economic measurements

The economic analysis was performed initially considering FI and feeding costs per each live weight gain for all treatment diets during the experimental period. The analysis was calculated (FI during the respective period multiplied by the feeding cost per gram per broiler chicken) according to the method described by **Ebling *et al.* (2013)** and **Ahmed *et al.* (2015)**. The prices of the experimental diets and live body weight were calculated according to the prices with the local Egyptian pound (EP) market at the time of the experimental period in June of the year 2019.

European production efficiency index (EPEI), net profit margin (NPM) and meat production cost (MPC) were calculated.

The equation used to calculate EPEI **(Hubbard broiler management guide, 1999)**, is as follows:

$$EPEI = \frac{(\text{Average grams gained/day} \times \text{\% survival rate}) \times 100}{\text{Feed conversion ratio} \times \text{age at the end period (day)}}$$

The equation used to calculate net profit margin (CFI Team, 2022)

Net profit margin = Net profit ⁄ Total revenue x 100

Statistical analysis

Statistical analysis was done using the GLM procedure of statistical analysis software of SAS Institute **(SAS ver. 9.2, SAS® 2009)** using one-way analysis of variance according to the following formula:

Yij = μ + Ti + eij

Where: Yij= The observation of the statistical measured, μ= The general overall mean, Ti= The effect of treatment, eij= The experimental random error.

Before analyses, arcsine transformation was done to normalize data distribution. The mean difference at $p \le 0.05$ was tested using Tukey's HSD (honestly significant difference) test.

RESULTS AND DISCUSSION

In tropical and subtropical locations, HS is considered to be one of the most serious issues in broiler production. Chickens are more sensitive to heat than other livestock during the summer, which has an adverse effect on the poultry industry **(Lara and Rostagno, 2013 and Jahejo *et al.*, 2016**), can affect health and welfare, and cause damage to several organs (**Bao et al. 2008, Lara and Rostagno, 2013 and Jahejo *et al.*, 2016**). Birds have a limited ability to regulate their body temperature, and a rise in body temperature caused by a higher ambient temperature or excessive metabolic activity may result in irreversible thermoregulatory events that might endanger the birds' lives **(Abbas *et al.*, 2017**). Thermal injuries have been discovered in the chicken business when the ambient environmental temperature exceeds the thermo-neutral zone (16–25° C) **(Abd El-Hack *et al.*, 2020).**

Dietary modifications are preferred over other techniques for alleviating the negative effects of high ambient temperature on oxidative stress and poultry performance because they are more practical and less expensive (**Sinkalu *et al.*, 2009; Singh *et al.,* 2012 and Attia *et al.*, 2018)**. According to recent research, amino acid supplementation enhanced gastrointestinal function, which resulted in increased broiler growth performance **(Laudadio *et al.*, 2012; Wijtten *et al.*, 2010**). Several studies indicated that feeding arginine levels greater than those recommended by the National Research Council (1994) can help broilers develop faster (**Fernandes *et al.*, 2009; Jahanian, 2009).**

The experimental results indicated that broiler chicks in the negative control group exposed to HS had significantly lowest final BW at 35 days of age by 10.86%, compared to the BW for the broiler in the positive control group (Table 2). Moreover, supplementation of the different levels of Arg/kg diet except 0.5g Arg recovery and recorded the significantly highest final BW compared with the positive control group at the end of the experiment (35 d of age). Also, the same trend of BW results was observed for BWG since broiler chicks in the negative control group had significantly lowest final BWG at 35 days of age by 12.23% compared to the BWG for the broiler in the positive control group. As generally Arg supplementation improved the BWG at 35 days of age compared to the negative control (HS group).

However, supplementation of different levels of Arg (0.5, 1.0 and 2 g Arg/ kg diet) were statistically equal and recorded the significantly highest BWG compared to the negative control group (Table 2). These results are in agreement with **Maini *et al.* (2007)** who indicated that during periods of HS, most of the production energy is diverted to thermoregulatory adaptations that result in decreased body weight. Also, **Barrett *et al.* (2019**) stated that body weights were significantly decreased due to HS exposure. **Geraert *et al.* (1996)** demonstrated that these reductions in BW were explained by decreased metabolic utilization of nutrients, spending less time eating to diminish metabolic heat production **(Syafwan *et al.*, 2012),** that reduced protein retention, and enhanced lipid deposition. However, supplementation of different levels of Arg significantly improved the BW compared to the HS group, during different experimental periods.

Table (2): Effect of dietary arginine supplementation on broiler chicks performance at 35 days of age

Treatments / Criteria	Control +	Heat Stress				SEM	P value
		Control-	0.5g Arg/ kg diet	1g Arg/ kg diet	2g Arg/ kg diet		
BW,35d(g)	1804 [a]	1608 [b]	1797 [a]	1858 [a]	1867 [a]	19.38	0.0003
BWG,7-35d(g)	1595 [a]	1400 [b]	1587 [a]	1651 [a]	1654 [a]	18.88	0.0002
FI,7-35d(g)	2963 [a]	2485 [b]	2615 [b]	2615 [b]	2595 [b]	42.89	0.0102
FCR,7-35d(g/g)	1.86 [a]	1.78 [a]	1.65 [b]	1.58 [b]	1.57 [b]	0.021	0.0001
Mortality	0.0	0.83	0.17	0.67	0.33	0.129	0.1149

[a,b] Means in the same row followed by different letters are significantly different at ($P \leq 0.05$).
SEM = standard error of mean; Arg= arginine; BW= body weight. FCR= feed conversion ratio

Exposing the broiler chicks to HS significantly decreased the amount of feed intake throughout the experimental period (7-35 days of age) compared to the positive control group by 16.13% (Table 2). However, supplementation of different levels of Arg had not complete recovery of decreased FI as a positive control group. The FCR which was estimated during 7-35 days of age was statistically equal between the positive and negative control groups, thus may be due to the decrease of the amount of FI, BW and BWG under HS conditions. Meanwhile, supplementation of different levels of Arg significantly improved the FCR compared with positive and negative control groups at the end of the experimental period (35 days of age), (Table 2). These results are in agreement with **Mashaly *et al.*, (2004); Younis (2007) and Sahin *et al.*, (2009**) who demonstrated that high ambient temperatures compromise performance and productivity by reducing FI, and decreasing nutrient utilization and feed efficiency. Also, **Temim *et al.* (2000) and De Souza *et al.* (2016)** showed that decreased broiler FI and FCR occur under HS**. Ebrahimi *et al.*, (2014)** reported that FCR improved significantly as the arginine supplementation in the broiler diet was increased from 100% of the requirement to 183%. The same results were obtained by **Kamel *et al.* (2017), Xu *et al.*, (2018) and Castro *et al.*, (2019)** observed that broiler diets supplemented with increasing the arginine level improved FCR. Likewise, **Ale Saheb Fosoul *et al.*, (2019)** and **Castro *et al.*, (2019)** demonstrated that FCR improved in birds with increasing the arginine level in the diet of broilers. Similarly, **Liu *et al.* (2019)** reported that FCR was optimum when 14.7 g/kg arginine was supplemented in the broiler diet. The improvement in BW and BWG reflected the improving the relative weight of dressing due to supplementation of Arg compared with the unsupplemented group (negative group). On the other hand, the improvement in broiler growth and FCR might be interpreted as a compensatory mechanism increasing the absorption of nutrients to more proximal sites. This is reflected in the improvement of the digestibility coefficient values of CP and EE (Table 3). These results are in agreement with **Löser *et al.*, (1999) and Laudadio *et al.*, (2012)** who indicated that several amino acids can promote gut function and integrity which has reflected in improving the nutrients digestibility gastrointestinal and subsequently growth performance of broilers.

Table (3): Effect of dietary arginine (Arg) supplementation on digestibility coefficient values of broiler chicks at 35 days of age

Treatments / Criteria %	Control +	Heat Stress				SEM	P value
		Control-	0.5g Arg/ kg diet	1g Arg/ kg diet	2g Arg/ kg diet		
Organic matter	85.13	85.20	85.17	85.23	85.23	0.035	0.6819
Dry matter	85.20	85.23	85.17	85.23	85.23	0.046	0.9018
Crud protein	77.87 [b]	74.87 [c]	78.93 [a]	77.90 [b]	77.63 [b]	0.065	0.0001
Ether extract	73.60 [b]	70.30 [c]	74.30 [a]	72.60 [b]	73.07 [b]	0.150	0.0001
Crud fiber	22.73 [c]	21.17 [c]	27.70 [a]	26.57 [ab]	24.80 [b]	0.346	0.0002

[a,b] Means in the same row followed by different letters are significantly different at (P≤0.05). SEM = standard error of mean.

Different relative weights of carcass characteristics measured were significantly affected at 35 days of age except for the relative weights of the intestine, which did not differ among the experimental groups (Table 4). The broiler chicks in the negative group exposed to

Table (4): Effect of dietary arginine supplementation on relative weights of carcass characteristics (g/100g LBW) of broiler chicks at 35 days of age

Criteria \ Treatments	Control+	Heat Stress				SEM	P value
		Control-	0.5g Arg/ kg diet	1g Arg/ kg diet	2g Arg/ kg diet		
Dressing, (g/100g LBW)	74.8 [a]	70.8 [b]	71.2 [b]	73.9 [a]	75.1 [a]	0.392	0.0007
Liver, (g/100g LBW)	2.13 [b]	1.99 [b]	2.46 [a]	2.40 [a]	2.38 [a]	0.034	0.0001
Spleen, (g/100g LBW)	0.137 [a]	0.091 [c]	0.110 [bc]	0.115 [b]	0.119 [ab]	0.0004	0.0020
Intestine, (g/100g LBW)	4.65	4.62	4.69	4.34	4.20	0.180	0.3740
Bursa, (g/100g LBW)	0.054 [a]	0.041 [b]	0.055 [a]	0.056 [a]	0.054 [a]	0.002	0.0427
Thymus, (g/100g LBW)	0.326 [a]	0.213 [b]	0.292 [a]	0.326 [a]	0.294 [a]	0.014	0.0020
Pancreas, (g/100g LBW)	0.217 [b]	0.306 [a]	0.245 [b]	0.243 [b]	0.244 [b]	0.010	0.0012
Abdominal fat, (g/100g LBW)	1.02 [b]	1.48 [a]	1.07 [b]	1.07 [b]	1.02 [b]	0.083	0.0406

[a,b] Means in the same row followed by different letters are significantly different at (P≤0.05).
SEM = standard error of mean; Arg= arginine; LBW= Live body weight

HS significantly decreased the relative weights of dressing, liver, spleen, bursa and thymus compared to those in the positive control group. Meanwhile, supplementation of different levels of Arg to the broiler diets under HS significantly improved the previous treaties compared with the relative weight of the negative control group and complete recovery of the relative weights compared to the positive control group. The broiler chicks in the negative control group exposed to HS significantly increased the relative weights of pancreas and abdominal fat compared to those in the positive control group. However, supplementation of different levels of Arg to the broiler diets under HS significantly improved the previous treaties compared with the relative weight of the negative control group (Table, 4). **Jiao *et al.*,**

(2010) reported that carcass yield, quality and breast muscle yield due to increasing dietary arginine levels than the NRC recommendation. The same results were reported by **Pirsaraei *et al.*, (2018)** who reported that arginine supplementation more than NRC recommendation significantly increased carcass yield and breast and thigh relative weights of Arian broiler chickens. On the other hand, some researchers reported that supplementation with different arginine levels had no significant effect on broiler organ weight and carcass traits (**Leitgeb *et al.*, 2004; Cengiz and Kucukersan, 2010). Khajali and Wideman (2010)** indicated that Arg stimulating the release of growth hormone, insulin, and insulin-like growth factor in the bloodstream **Silva *et al.*, (2012)**. Also, **Khajali and Wideman (2010)** reported that L-Arg is a substrate for the biosynthesis of many molecules, including protein, nitric oxide, creatine, ornithine, glutamate, polyamines, proline, glutamine, agmatine, and dimethyl arginines **(Allen, 1999; Deng *et al.*, 2005; D'Amato and Humphrey (2010)**.

Exposing birds to HS causes oxidative stress, resulting in a change in the blood biochemical stress parameters (Table 5), which is a valuable tool to monitor the health situation and determine the severity of the heat stress in heat-stressed (HS) broilers (**Habashy *et al.*, 2017; Hosseini-Vashan and Raei-Moghadam, 2019; Dapeng *et al.*, 2020 and Kraus *et al.*, 2021**). Also, HS causes an increase in respiratory rate which lowers plasma carbon dioxide and bicarbonate levels and resulting in respiratory alkalosis, which alters the acid-base balance and blood pH, accompanied by lowered PCV. In the present study, the RBCs, Hgb and PCV for the negative control were significantly reduced by 4.0, 14.7 and 7.7%, respectively compared to the positive control group (Table 5). These results are in agreement with the evidence that the decrease in total RBCs count and life span, which in turn decreases Hgb and PCV due to positive relationships between the three criteria under HS (**Vo *et al.*, 1978**). Also, **Ismail (1988)** reported that the reduction of PCV and Hgb in the hot season could be due to the reduction of the concentration of circulating RBCs, which reduces the oxygen uptake and hence less metabolic heat production at a cellular level and/or attributed to the increase of water intake. The present study indicated a significantly increased in lymphocytes and monocytes percentages for the negative control group by 14.5 and 17.7% compared to the positive control group. On the other hand, eosinophils, heterophils and H/L ratio were increased by 14.4, 21.4 and 41.3% in the negative control compared to the positive control group (Table 5). These results are in agreement with **Altan *et al.* (2003**) who observed that exposure broilers to heat stress caused a decrease in lymphocyte and an increase in heterophils proportions. Also, **Hamad (2010)** reported that the PCV was significantly lower during summer compared with winter, the Hgb concentration was significantly higher in the exotic breed than in the local breed in both seasons and H/L ratio was significantly higher during summer than the winter. In the same respect, **Attia and Hassan (2017)** indicated that PCV was significantly decreased due to the CHS treatment when compared to the thermoneutral group. **Altan *et al.*, (2003)** reported heat stress caused a significant decrease in haematocrit values from 34.57 to 31.35 %. Similarly, **El-Badry (2004)** observed that the PCV increased when chickens were exposed to lower temperatures as compared to higher environmental temperatures. **Attia *et al.*, (2011)** reported that heat stress had a negative effect on blood PCV and Hgb. Also, **Al-Daraji and Salih (2012)** found that broiler chickens exposed to heat stress resulted in a significant decrease in RBC, Hgb and PCV. However, the results clearly indicated that supplemented broiler diets, exposed to HS condition, with different levels of Arg were improved and complete recovery of the RBCs, Hgb and PCV% as the positive control group and at the same time, they were statistically equaled. On the other hand, both of WBCs counts and basophils percentages were statistically equal among different treatment groups. Moreover, lymphocytes and monocytes percentages were improved for the groups supplied with1.0 and 2.0 g Arg/Kg diet compared with the concentrations recorded for the negative control group. The same results were reported by **Al-Daraji and Salih (2012)** who indicated that adding 0.02, 0.04 and 0.06% arginine to the broiler diet resulted in a significant increase in RBCs, Hgb and PCV while against the present study they indicated that H/L ratio was significant decrease under HS condition compared to the control group. **Zulkifli *et al.*, (2003)** reported that the H/L ratio is a reliable indicator of avian stress. Broilers exposed to various forms of stress have clearly shown an increase in heterophils and a decrease in lymphocytes, which leads to an increase in the H/L ratio (**Feddes *et al.*, 2002).** Heat exposure releases excessive glucocorticoids, causing the dissolution of lymphocytes which may cause lymphopenia, also, heat and RH stress resulted in an increased H/L ratio (**Daghir, 1995)**. **Kamel *et al.* (2017)** showed that the H/L ratio was significantly increased in HS broilers compared to the control. **Hamad (2010)** reported that the H/L ratio was significantly higher during summer than the winter. However, **Toghyani *et al.*, (2019)** indicated that blood leukocyte counts were not influenced by Arg and Threonine inovo administration.

Table (5): Effect of dietary arginine supplementation on blood hematological parameters of broiler chicks at 35 days of age

Treatments / Criteria	Control+	Heat Stress				SEM	P value
		Control-	0.5g Arg/ kg diet	1g Arg/ kg diet	2g Arg/ kg diet		
RBCs, (10^6/mm^3)	1.73 ^{a}	1.66 ^{b}	1.73 ^{a}	1.81 ^{a}	1.81 ^{a}	0.018	0.0002
Hgb, (g/dl)	13.6 ^{b}	11.60 ^{c}	14.2 ^{a}	14.3 ^{a}	14.75^a	0.191	0.0001
PCV, (%)	41.6 ^{b}	38.40 ^{c}	44.0 ^{ab}	44.0 ^{ab}	45.7 ^{a}	0.581	0.0002
WBCs, (10^3/mm^3)	23.7	24.4	24.3	23.5	25.1	0.237	0.0555
Lymphocytes, (%)	47.5 ^{a}	40.6 ^{d}	43.9 ^{c}	45.0 ^{b}	45.6 ^{ab}	0.291	0.0001
Monocytes, (%)	18.6 ^{a}	15.4 ^{b}	16.4^b	17.0 ^{ab}	17.2 ^{ab}	0.317	0.0155
Basophils, (%)	1.00	0.70	1.00	1.00	0.70	0.076	0.2548
Eosinophils, (%)	10.3 ^{c}	12.30 ^{a}	11.3 ^{b}	11.3 ^{b}	11.3 ^{b}	0.151	0.0011
Heterophils, (%)	22.0 ^{b}	26.7^a	27.4 ^{a}	27.8 ^{a}	27.6 ^{a}	0.335	0.0001
H/L Ratio	0.468 ^{b}	0.660 ^{a}	0.628 ^{a}	0.620 ^{a}	0.606 ^{a}	0.011	0.0001

SEM = standard error of mean; Arg= arginine; RBC= red blood cell; Hgb= hemoglobin; PCV=packed cell volume; WBC= white blood cell and H/L Ratio= heterophils to lymphocyte ratio.
^{a,b} Means in the same row followed by different letters are significantly different at (P≤0.05).

Results indicated that the positive and negative control groups had significantly the lowest EE and REE compared with the other experimental groups (Table 6). However, supplementation with 2g Arg/kg diet had significantly improved and recorded the best EE and REE, also no significant differences were recorded among the different groups supplied with Arg. Feeding on a diet supplemented with different levels of Arg had a significantly lower MPC and NPM than the positive and negative control groups. However, chicks feed diets supplemented with different levels of Arg were statistically equal. European production efficiency factor was giving the same results as EE and REE, since they indicated that the positive and negative control groups had significantly lowest EPEI compared with the other experimental groups. Also, EPEI for the chicks' feed diet supplemented with different levels of Arg was improved compared with that recorded for positive and negative control groups. On the other hand, the chicks feed diet supplemented with 2g Arg/kg diet recorded the highest EPEI compared with the other experimental groups, but it's statistically equal to the group fed 1g Arg/kg diet.

Table (6): Effect of dietary arginine supplementation on feed economic efficiency of broiler chicks during 7-35 days of age

Criteria \ Treatments	Heat Stress					SEM	P value
	Control+	Control-	0.5g Arg/ kg diet	1g Arg/ kg diet	2g Arg/ kg diet		
BWG (7-35), g	1.80 [a]	1.62 [b]	1.80 [a]	1.86 [a]	1.87 [a]	0.019	0.0003
Total feed cost, EP (A)	19.57 [a]	16.87 [b]	7.52 [b]	17.52 [b]	17.50 [b]	0.285	0.0153
Total cost, EP (B)	24.6 [a]	21.9 [b]	22.7 [b]	22.7 [b]	22.6 [b]	0.632	0.0207
Total revenue, EP (C)	57.7 [a]	51.9 [b]	57.5 [a]	59.5 [a]	59.7 [a]	0.583	0.0003
Net revenue, EP (D)	33.07 [b]	30.0 [c]	36.8 [ab]	26.68 [b]	30.01 [a]	0.438	0.0001
EE	134 [b]	137 [b]	155 [a]	163 [a]	164[a]	2.323	0.0001
REE	100 [b]	106 [b]	120 [a]	126 [a]	127 [a]	1.528	0.0001
NPM	56.20 [b]	59.42 [ab]	61.52 [a]	61.73 [a]	60.64 [a]	0.022	0.0007
MPC	0.340 [a]	0.325 [a]	0.305 [b]	0.294 [b]	0.291[b]	0.004	0.0001
EPEF	319 [c]	298 [c]	353 [b]	378 [ab]	385 [a]	17.7	0.0001

SEM= standard error of mean; Arg= arginine; BWG= body weight gain; EE= economic efficiency; REE= relative economic efficiency; MPC= Meat production cost; EPEF= economic production efficiency factor.
[a,b] Means in the same row followed by different letters are significantly different at ($P \leq 0.05$). Total feed cost (A, the cost of this gain) = Total FI/kg (Starter period plus grower and finisher period) × Price per kg FI (According to each treatment). Total cost (B)= Total feed cost (A) + the other cost. Total revenue (C, the selling cost of the obtained gain) = LBWG × Price per kg LBW (32 EP/kg LBW); Net revenue (D) = Total revenue (C) - Total cost (B). Economic efficiency (%) = (C/B) ×100; Relative economic efficiency (%) assuming the control treatment equal = 100%. Net Profit margin (NPM) = Net. Profit ⁄ Total revenue x 100

In conclusion, the present results indicated that under HS, supplementation of dietary Arg (1g/ kg) to broiler diets could be apple to elevate the adverse effect of HS and improve the productive performance, carcass traits, digestibility, hematology and economic efficiency.

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الملخص العربي

تأثير إضافة الأرجنين على الكفاءة الإنتاجية وصفات الذبيحة وصفات الدم الطبيعية والكفاءة الإقتصادية لبدارى التسمين تحت ظروف الإجهاد الحراري

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تم استخدام ١٨٠ كتكوتاً غير مجنس عمر ٧ أيام من سلالة الأربورإيكرز لدراسة تأثير إضافة مستويات مختلفة من الأرجنين على الأداء الإنتاجي وصفات الذبيحة وصفات الدم الطبيعية والكفاءة الإقتصادية لكتاكيت التسمين تحت ظروف الإجهاد الحراري. تم توزيع الطيور عشوائياً على ٥ مجموعات تجريبية كل منها به ٦ مكرارت وبكل مكررة ٦ كتاكيت بمتوسط وزن ٢٠٩ جم±2.63 من عمر ٧-٣٥ يوماً. تم وضع الطيور فى البطاريات مقاس (٥٥×٥٠×٣٥)، وكانت المجموعات التجريبية كالتالي: المجموعة الأولي تم تغذيتها على عليقة بدون أي إضافات ولم تعرض للإجهاد الحراري (الكنترول الموجب)، بينما تعرضت المجاميع الأخرى للإجهاد الحراري وتغذت على علائق تحتوي على ٠، و٠,٥، و١ و٢ جم أرجنين/ كجم علف، على التوالي، تم استخدام العلف طبقاً للتوصيات الغذائية للـ NRC. انخفض وزن الجسم النهائي والزيادة في وزن الجسم للكتاكيت المعرضة للإجهاد الحراري مقارنة بمجموعة الكنترول الموجب. وأدت إضافة المستويات المختلفة من الأرجنين إلى تحسن في وزن الجسم والزيادة في وزن الجسم ومعدل التحويل الغذائي مقارنة بمجموعة الكنترول السالب. وزاد عدد كرات الدم الحمراء والهيموجلوبين وحجم كرات الدم الحمراء للكتاكيت المغذاة على الأرجنين مقارنة بمجموعة الكنترول الموجب. اضافة الأرجنين بمستويات مختلفة تحت ظروف الإجهاد الحراري أدت إلى تحسن في الأوزان النسبية للتصافي والكبد والطحال وغدتي البرسا والتيموسية مقارنة بمجموعتي الكنترول السالب والموجب. وتحسنت الكفاءة الاقتصادية باضافة المستويات المختلفة من الأرجنين حيث سجلت أفضل كفاءة اقتصادية، وكفاءة اقتصادية نسبية، وهامش الربح الصافي، وانخفضت تكلفة إنتاج اللحم مقارنة بمجموعات الكنترول الموجب والسالب.

الخلاصة:

تشير النتائج الحالية إلى أن إضافة الأرجنين لعلائق كتاكيت التسمين تساعد فى تقليل التأثير الضار للإجهاد الحرارى وتحسن الأداء الإنتاجي وصفات الذبيحة وصفات الدم الطبيعية والكفاءة الإقتصادية.

الكلمات الدالة:

كتاكيت التسمين – الأداء الإنتاجي – صفات الذبيحة – الدم – الكفاءة الإقتصادية.