Nutritional strategies to alleviate heat stress effects through feed restrictions and feed additives (vitamins and minerals) in broilers under summer conditions

Abdelhameed Salah Abdelhameed Mohamed · Alexander Robertovich Lozovskiy · Amany Muhammad Ahmed Ali

ASA Mohamed^{A,B} (Corresponding author) · **AR Lozovskiy**^B
· **AMA Ali**^C
email: abdalhmed.salah@yahoo.com

^ADepartment of Animal and poultry production, Faculty of Agriculture, Minia University, EL-Menia, Egypt.

^BChair of Zootechny & Agricultural Produce Processing Technology, Faculty of Agribusiness, Technologies, & Veterinary Medicine, Astrakhan State University, Russia.

^CDepartment of Botany and Microbiology, Faculty of Science, Minia University, EL-Menia, Egypt.

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Abstract This experiment was aimed to determine the best strategies for alleviating the detrimental effects of heat stress by feed restriction (FR) in hot times and dietary supplementation with Vit.+Min. (vitamins and minerals) by their impacts on growth parameters, mortality rate, serum biochemistry indices and carcass traits of broiler under summer conditions in the open-sided house. A total of 420 broilers of Ross 308 (unsexed 7-day-old) were equally divided into 7 treatments (T). Throughout the experiment, chicks in T1 (control) fed ad libitum on basal diets, FR was applied in T2, T3 and T4 as followed 2, 3, 4 hours (h) without feeding respectively. Supplemental vitamin C (Vit.C) + vitamin E (Vit.E) + chromium (Cr) + zinc (Zn) as followed 100+100+0.5+50 (T5), 150+150+1.0+75 (T6), 200+200+1.5+100 (T7) mg/kg diet respectively. It was found that FR and feed additives improved body weight, weight gain, and significantly decreased feed conversion, mortality rate, and abdominal fat of stressed broiler. Applying FR (3, 4 h) and supplementation with Vit.+Min. (T6, T7) significantly increased total serum protein and statically decreased total serum cholesterol. Overall results conducted that FR for 3 h (T3) and dietary supplementation (T7) have the most significant results which indicate the vital role of FR and supplementation with Vit.+Min. in stressed broilers.

Keywords: broilers, feed additives, feed restriction, growth, heat stress

Introduction

Heat stress (HS) is one of the critical environmental stressors especially in opening poultry houses which reflects the difficulties for controlling environmental stressors (Lara and Rostagno 2013). Moreover, modern strains of broiler have been produced to cover the demands of a producer regarding quantity so that, broiler chicks are more highly sensitive for stressors such as HS (Fouad et al 2016). HS is a responsible

for the imbalance between reactive oxygen species and antioxidants which lead to damage of cell structures such as proteins, lipids, nucleic acids and membranes of the cell (Tan et al 2010; Kumbhar et al 2018). The harmful effects of HS on broiler production by markedly reducing body weight (BW), body weight gain (BWG), feed intake (FI), feed efficiency, meat quality, immunity, and safety (Zhu et al 2017; Papadopoulou et al 2017). A reduction in the concentration of plasma antioxidants (Vit.C, Vit.E, and Zn) are harmfully correlated with the high loss caused by oxidation in chicks reared under stress conditions (Kumbhar et al 2018). Furthermore, chicks reared under HS (high temperatures, 34°C) have a more fat deposition in the carcass (Zhang et al 2012).

To overcome HS effects in broiler chicks through nutritional management strategies: two ways have been used 1) feed restriction (FR) methods (Abdel-Hafeez et al 2017); 2) dietary supplementation of feed additives (antioxidants, minerals, vitamins, amino acids, probiotics, prebiotics, etc.) (Ali et al 2018).

Under HS, methods of FR have been recommended to decrease these losses and improve production efficiency. FR strategies can be in the form of qualitative by reduces nutrients intake (Attia et al 2017) or quantitative by limiting the time of the feed access (Jahanpour et al 2015). The best age of chicks for applying FR is between the second and third weeks of age, while first 7 days of age FR can cause intestinal underdevelopment and tend to a decline in productivity (Saber et al 2011). FR can improve feed conversion ratio (FCR) and reduce fat deposition of the carcass and metabolic diseases in broilers (De Antonio et al 2017).

Vit.C (L-ascorbic acid) is an antioxidant and has a main role in metabolic activity by declining the functions as an electron donor (Khan et al 2012). However, Vit.C can be synthesized regularly in broilers (khan 2011). Previous studies have been recommended in broiler diets as a supplement to

combat HS as a result of the high temperatures impair the absorption of Vit.C, which leads to increase the dietary requirement of Vit.C (Gous and Morris 2005). Supplemental Vit.C can improve growth and immunity responses under HS in broilers (Attia et al 2011). Vit.E (α -tocopherol) is considered one of the essential antioxidants; it has a central role in cellular membranes particularly those in muscle cells (Raederstorff et al 2015). Vit.E could raise growth indices and immunity parameters (El Dein et al 2013), it can increase antioxidant capacity and lower lipid peroxidation of broilers by supplemental Vit.E (Cheng et al 2017).

Trace minerals play the central role for all metabolic functions in broiler chicks including the secretion of the digestive system by improving nutrient digestibility (Khan et al 2012). Cr has been utilized for feed efficiency to improve BW and relative organs in broiler chicks; therefore, Cr is considered a popular mineral supplement, as a result of it acts a dynamic role in enhancing the retention of other essential elements in blood and decreases their excretion (Sahin et al 2017). Zn is one of the essential nutrients which is a cofactor for 200 enzymes in broiler chicks. Thus, it has the central role in antioxidant capacity, growth, immunity, and digestion of nutrients by interaction with other minerals in the gut (Naz et al 2016).

Previous studies have investigated the impacts of FR, Vit.C, Vit.E, Cr, and Zn as an individual effect. But, there is no information available about the comparison between FR methods and feed additives (by combination Vit.+Min.) under HS. Therefore, the goal of this research was to determine the most significant strategies of FR, and dietary supplementation can markedly moderate HS effects in broilers under summer conditions in the opening house.

Materials and Methods

Chicks and management

This study was carried out in South Russia (Astrakhan State University) during the summer months (July and August 2018). In the open-sided house, 420 one-day-old (Ross 308) broilers were purchased and kept in floor pens from 1 (42.70 $\pm$ 0.50g) to 35 days of age. Broiler chicks were reared on a chopped mixture of wood shavings and wheat straw. The initial 7 days of brooding, chicks were brooded together and fed a basal diet with feeding and drinking *ad libitum*. At 7-day old, chicks were weighed and randomly classified (8 chicks/m²) into 7 experimental groups of 60 chicks each. Every group (T) contains three replicates of 20 chicks each. The alighting period was 23 hours per day throughout the experimental period. All groups were fed on commercial diets (starter and finisher) that provided by the National Research Council, (1994). The chemical analyses of diets are detailed in Table 1. The composition of the nutrients was determined

according to the Association of Analytical Communities (A.O.A.C) methods (2005). The experiment treatments consist of 7 treatments (Table 2).

During the whole trial period, two feeding periods were applied while, the starter period (1-21 days) and finisher period (22-35 days). The temperature of brooding (1-7 days) was 33 to 35 °C with relative humidity (RH) was ranged from 65-70%. The ambient temperatures and relative humidity were recorded daily while every 6 hours except for the period from 12:00 pm to 16:00 pm, it was every hour. The temperatures and relative humidity (recorded by using electronic thermometer/hygrometer Oregon Scientific BAR268HG-w) over all the period (8-35 days of age) are detailed in Figure 1.

Growth parameters and mortality rate

Every week, BW and FI (was adjusted for mortality) were registered which, BWG and FCR were calculated. FCR was determined and corrected for the number of broiler chicks per replicate while calculated by kilogram (kg) of FI per 1 kg of live BWG. Morality rate (M %) was recorded daily.

Serum biochemistry indices

At day 35, 3 blood samples per replicate were collected (9 samples per treatment) by the wing vein (2.5 ml of blood) in clean centrifuge tubes for measurement of blood parameters then slaughtered to measure carcass traits. The samples were left for 20 minutes at room temperature to clot. Then, samples were centrifuged at 3,000 rpm for 15 minutes (by using Centrifuge OIHH- 3) to separate serum from blood. Serum blood samples stored at -20°C for measurement of total protein, uric acid, creatinine, glucose, triglycerides, total cholesterol. These parameters were determined colorimetrically using commercial kits (produced by Olvex Diagnosticum, Russia) according to the manufacturer's recommendations.

Carcass traits

At day 35 of age, after 12 hours of fasting, three chicks were chosen randomly from each replicate (9 chicks per treatment) for slaughtering to estimate some carcass traits. The feathers were picked and eviscerated carcass weight (g), liver, spleen and abdominal fat separately weighted, they are presented as a percent of live BW.

Statistical analysis

Data are presented as mean $\pm$ SE. The statistical analysis processing of data was examined by one-way ANOVA, analysis of variance, using a general linear model (GLM) procedure of SAS Institute (2003). Duncan's test was used to study the significance degrees among means (Duncan 1955).

Table 1 Ingredient and nutrient composition of the control diet.

Ingredient, %	Starter (1-21 days of age)	Finisher (22-35 days of age)
Yellow corn	53.90	56.35
Soybean meal	32.10	3.50
Corn gluten meal	5.80	30.87
Sun flower oil	4.20	5.55
Dicalcium phosphate	1.80	1.68
Sodium chloride	0.30	0.30
Limestone	1.30	1.20
DL-methionine	0.15	0.10
Lysine	0.15	0.15
Vitamin-mineral premix*	0.30	0.30
Analyzed chemical composition		
Dry matter	92.23	92.01
Crude protein	22.82	20.76
Crude fiber	3.05	3.22
Ether extract	6.45	7.92
Calculated chemical composition		
Metabolizable energy (MJ/kg)	12.98	13.40
Calcium	0.99	0.93
Available phosphorus	0.47	0.45
Methionine+ Cystine	0.90	0.79

*Provided per kilogram of diet: vitamin A, 12,500 IU; vitamin D3, 4000 IU; vitamin E, 30 IU; vitamin K, 2.3 mg; thiamine, 2.2 mg; riboflavin, 8 mg; pantothenic acid, 24.3 mg; niacin, 65 mg; pyridoxine, 4 mg; folic acid, 1.2 mg; biotin, 0.25 mg; vitamin B12, 3 mg; choline, 600 mg; iron from ferrous sulfate, 60 mg; copper from copper sulfate, 7.5 mg; manganese from manganese oxide, 125.1 mg; zinc from zinc oxide, 110 mg; iodine from ethylene diamine dihydride, 1.8 mg; selenium from sodium selenite, 0.35.

Table 2 The experimental design.

Treatments	Feed restriction	Vitamins (mg)		Minerals (mg)	
	Number of hours without feeding (timing, pm)	Vit.C (L-ascorbic acid, 99%)	Vit.E (DL- α -Tocopherol acetate, 50 - 52.6%)	Cr (chromium picolinate, CrPic, 12.42%)	Zn (ZnSO ₄)
T1 (control)	-	-	-	-	-
T2	2 (12:00-14:00)	-	-	-	-
T3	3 (12:00-15:00)	-	-	-	-
T4	4 (12:00-16:00)	-	-	-	-
T5	-	100	100	0.5	50
T6	-	150	150	1.0	75
T7	-	200	200	1.5	100

Results

Growth parameters and mortality rate

Concerning FR impacts and dietary supplementation (Vit.C, Vit.E, Zn and Cr) during the experimental periods, it can be remarked positive effects on BW (Table 3), BWG

(Table 3), FI (Table 4), FCR (Table 4) and M % (Table 5) compared with the control group (T1) under high temperatures (32 °C).

FR for 3 h (T3) in hot times (12:00-15:00) improved ($P<0.05$) BW, in the same way, supplemental Vit.+Min. (T6, T7) enhanced ($P<0.01$) BW through the experimental periods

(7-21, 22-35 days) compared with the control group (Table 4). However, there was no significant effect recorded with FR (2, 4 h) on BW. While stressed broiler chicks that fed dietary supplementation with 200 mg Vit.C+ 200 mg Vit.E+100 mg Zn+ 1.5 mg Cr (T7) had a higher BW compared with broilers in the other groups.

Restricted broilers in T3 had higher BWG followed by broiler chicks in T2 compared with the control (T1), but BWG was not significantly influenced by FR (4 h) during the periods of the experiment (Table 3). As compared with the control group, all the levels of supplementation significantly enhanced BWG throughout all periods of trial. At the entire of the experimental period (7-35 days), broilers in T7 followed by T6 had the highest values of BWG than those in the control group and other experimental treatments.

Table 4 showed that FR for 2 h (T2) had no effect on FI at the whole experimental period (7-35 days). Nevertheless,

FR for 3 and 4 h (T3 and T4) can lead to a statistical decline in FI particularly in restricted broilers entire all the experimental periods except the first two weeks (7-21 days). Supplemental Vit.+Min. increased ($P<0.01$) FI from 7-21 days of age but markedly decreased from 21-35 days of age. FI was not influenced by supplementation at all over the 28 days of the experiment (7-35 days). Applying FR in T4 presented the lowest ($P<0.01$) FI compared with the other treatments during all experimental period.

In general, FR and supplemental (Vit.+Min.) at all experimental periods significantly improved FCR compared with the control (Table 5). Concerning the FCR, restriction for 3 and 4 h (T3, T4) and adding feed additives (T6, T7) improved feed efficiency by 10.4, 10.9, 7.8, and 11.4% respectively compared with the control at all over 28 days (7-35 days).

Figure 1 Ambient temperature (C°) and relative humidity (%) during the experimental period under summer conditions.

Table 3 Body weight (BW) and body weight gain (BWG) of broilers as affected by feed restriction (FR), dietary supplementation with Vit. (C, E) and Min. (Cr, Zn) under summer conditions.

Treatments	BW (g)			BWG (g)		
	7 day	21 day	35 day	7-21 days	22-35 days	7-35 days
T1 (control)	161.48	793.01 ^d	1779.66 ^d	631.53 ^d	986.65 ^d	1618.18 ^e
T2	162.03	807.70 ^{cd}	1828.42 ^d	645.67 ^{cd}	1020.72 ^c	1666.38 ^d
T3	157.27	835.68 ^{ab}	1864.49 ^c	678.42 ^{ab}	1028.81 ^c	1707.22 ^c
T4	157.12	802.25 ^{cd}	1778.59 ^d	645.13 ^{cd}	976.34 ^d	1621.48 ^e
T5	160.38	817.82 ^{bc}	1863.05 ^c	657.43 ^{bc}	1045.23 ^c	1702.67 ^c
T6	163.52	837.34 ^{ab}	1920.37 ^b	673.83 ^{ab}	1083.03 ^b	1756.85 ^b
T7	163.68	850.25 ^a	1965.51 ^a	686.57 ^a	1115.26 ^a	1801.83 ^a
SEM	2.78	6.74	9.52	6.71	7.75	8.35
Significance	NS	**	**	**	**	**

a,b,c,d,e – means with different letters in the same row are significantly different at ($P<0.05$).
 *, ** indicates significant at $P<0.05$, $P<0.01$ respectively. SEM, standard error of the mean.
 NS, not significant. Body weight was measured weekly but the results of 7, 21 and 35 are presented in the table.

Table 4 Feed intake (FI) and feed conversion ratio (FCR) of broilers as affected by feed restriction (FR), dietary supplementation with Vit. (C, E) and Min. (Cr, Zn) under summer conditions

Treatments	FI (g)			FCR		
	7-21 days	21-35 days	7-35 days	7-21 days	22-35 days	7-35 days
T1 (control)	886.08 ^b	2240.94 ^a	3127.02 ^a	1.40 ^c	2.27 ^a	1.93 ^a
T2	963.33 ^a	2130.33 ^{bc}	3093.67 ^a	1.49 ^a	2.09 ^b	1.86 ^b
T3	969.00 ^a	1986.00 ^d	2955.00 ^b	1.43 ^{abc}	1.93 ^{cd}	1.73 ^d
T4	916.00 ^b	1878.67 ^e	2794.67 ^c	1.42 ^{bc}	1.92 ^{de}	1.72 ^d
T5	965.85 ^a	2167.60 ^b	3133.45 ^a	1.47 ^{ab}	2.07 ^b	1.84 ^b
T6	984.88 ^a	2148.65 ^b	3133.53 ^a	1.46 ^{abc}	1.99 ^c	1.78 ^c
T7	995.38 ^a	2084.08 ^c	3079.46 ^a	1.45 ^{abc}	1.87 ^e	1.71 ^d
SEM	14.51	15.36	25.98	0.02	0.02	0.01
Significance	**	**	**	NS	**	**

a,b,c,d – means with different letters in the same column are significantly different at ($P < 0.05$). *, ** indicates significant at $P < 0.05$, $P < 0.01$ respectively. SEM, standard error of the mean. NS, not significant. Feed intake was measured weekly but the results of 7, 21 and 35 are presented in the table.

Mortality rate

No dead birds were observed in the first two weeks (7-21) at all experimental treatments (Table 5). However, M % increased notably in the last week of the experimental period (28-35 days). During the growing period (7-35 days), FR decreased M % by 57.2 %, 71.5 % and 85.7% (T2, T3, T4 respectively) compared with the control group. In the same way, supplementation with Vit.+Min. reduced M % by 42.8 %, 71.5% and 85.7% (T5, T6, T7 respectively).

Table 5 Mortality rate (M%) as affected by feed restriction (FR) and dietary supplementation with vitamins (C, E) and minerals (Cr, Zn) under summer conditions.

Treatments	Mortality Rate (M%)		
	21-28 days of age	28-35 days of age	7-35 days of age
T1 (control)	3.33	8.77	11.67
T2	1.67	3.51	5.00
T3	0	3.51	3.33
T4	0	1.75	1.67
T5	0	7.02	6.67
T6	0	3.51	3.33
T7	0	1.75	1.67

Serum biochemistry indices

As shown in Table 6, in general, FR (3 and 4 h) and supplemental Vit.C, Vit.E, Cr, Zn (T6 and T7) significantly increased total serum protein and markedly reduced creatinine, uric acid, glucose, triglycerides, and total cholesterol. Restricted broilers in T4 and those fed diets with

feed additives (T7) showed the least serum creatinine, uric acid, glucose, triglycerides, and total cholesterol among the tested treatments and the control. Furthermore, broiler chicks which fed diets with 200 mg Vit.C+ 200 mg Vit.E+1.5 mg Cr + 100 mg Zn (T7) had the highest values ($P < 0.01$) in serum total protein followed by T3, T4 and T6 compared with the other treatments and the control.

Carcass traits

Applying FR and supplementation can able to improve the carcass characteristics of broilers by clearly increased carcass yield (%) and significantly declined abdominal fat (%) but did not differ in liver yield (%). FR (T4, T6) and dietary supplementation (T7) recorded the higher carcass yield (%) compared with other treatments and the control. Also, broiler chicks in T4 (FR, 4 h) and T6 (supplementation) had higher spleen yield (%), and lower abdominal fat (%) than those in the other treatments (Table 7).

Discussion

This experiment aimed to compare different nutritional strategies for mitigating HS effects through FR methods (2, 3, 4 h) and different levels of combination Vit.C, Vit.E, Cr and Zn in broilers under summer conditions. In depending on the given results of this study, able to determine the best strategies from FR methods (in timing) and feed additives (levels of Vit.+Min.) which can moderate the adverse effects of HS. In addition, it directs to improving broiler production and decreasing M %. To our knowledge, there is no data about experiments planned to compare FR methods and supplemental Vit.+Min. in broilers under summer conditions (HS).

Table 6 Blood parameters as affected by feed restriction (FR) and dietary supplementation with vitamins (C, E) and minerals (Cr, Zn) under summer conditions.

Treatments	Total protein (g/l)	Creatinine (mg/dl)	Uric acid (mg/dl)	Glucose (mmol/l)	Triglycerides (mg/dl)	Total cholesterol (mg/dl)
T1 (control)	43.37 ^c	0.50 ^a	10.91 ^a	10.07 ^a	128.93 ^a	132.62 ^a
T2	43.03 ^c	0.45 ^b	10.93 ^a	9.64 ^{ab}	114.38 ^b	130.84 ^a
T3	50.67 ^b	0.40 ^{cb}	10.28 ^b	7.64 ^d	94.64 ^c	125.30 ^b
T4	50.97 ^b	0.38 ^{cd}	9.27 ^c	7.14 ^e	72.88 ^d	122.84 ^{bc}
T5	44.73 ^c	0.44 ^b	10.78 ^a	9.48 ^b	127.38 ^a	129.37 ^a
T6	49.66 ^b	0.40 ^{cb}	9.99 ^b	8.72 ^c	106.64 ^b	122.07 ^{bc}
T7	53.17 ^a	0.34 ^d	9.14 ^c	7.09 ^e	72.55 ^d	120.83 ^c
SEM	0.61	0.01	0.13	0.16	3.67	1.15
Significance	**	**	**	**	**	**

a,b,c, d – means with different letters in the same column are significantly different at ($P < 0.05$). *, ** indicates significant at $P < 0.05$, $P < 0.01$ respectively. SEM, standard error of the mean.

Growth performance and mortality

During the whole experimental period (7-35 days of age), FR for 3 h (T3) in hot times significantly enhanced BW, BWG, FI, FCR, and M % compared with the control. Although, restricted broilers in T2 and T4 (2, 4 h) showed BW similar ($P \geq 0.05$) to broilers in the control group, can notice an economic advantage over the control group by improving feed efficiency and safety under HS. These results are agreement with Shamma et al (2014) who indicated that applied FR for 4 h (for 2 weeks of age) in broiler chicks improved final BW, BWG, FCR and decreased total FI and M % under summer conditions (30 °C, RH 45%). During the growing period (1-35 days), FR for 12 h daily (from 1 to 21 days) could be helpful rearing management by decreased FI and FCR without detrimental on performance (Azis et al 2019). Also, restricted broilers (by reducing feed intake to 25 % of ad libitum intake from one-day to 28 days of age) under summer conditions had a notable decrease in FI, FCR and M %, on the other hand, decreased BW and BWG compared with ad libitum feeding of stressed broilers (Abu-Dieeh 2006).

From this study, the present results provided evidence that restricted broilers can elicit compensatory growth after a period of retardation (restricted period). Meanwhile, limited feeding improves FCR, reduces sudden death syndrome, and ascites (metabolic diseases) through decreasing the metabolic rate (by decreasing FI), consequently reduced hypoxemia in broilers (Sahraei 2012, Julian 2000). FR can reduce heat production, increment speed of body temperature and M % of broiler chickens exposed to HS. Also, a reduction in metabolic rate (by FR) per unit of weight is related to a thermoregulatory advantage for stressed broilers (Syafwan et al 2011). Therefore, restriction in hot times can stimulate compensatory growth and improved heat tolerance of restricted broilers.

A combined effect of Vit.C, Vit.E, Cr, and Zn improved BW by approximately 4.69%, 7.91 and 10.44% (in T5, T6, and T7 respectively), when the values of FI did not differ at the growing period (7-35 days) compared with the control group. Besides, the results of supplementation on BWG took the same trend of final BW as a result of significantly improving in FCR. Moreover, adding Vit.+Min. to stressed broiler diets achieved a marked decrease in M % from 11.67% in control to 6.67, 3.33, and 1.67% (in T5, T6, and T7 respectively). These findings are agreement with Tawfeek et al (2014) who reported that supplementation with 250 mg Vit.C + 250 mg Vit.E or 0.5 mg Cr to stressed broilers (36 °C, RH 75%) significantly increased BW and BWG, decreased FCR and M % but did not change FI. In contrast, Ali et al (2018) reported that adding Vit.E, Zn, Cr individually or in a combination to broiler diets increased FI. The positive effect of combination Vit.+Min. on growth parameters and M % may be due to the impact of 250 mg Vit.C, Vit.E, 50 mg Zn, 0.7 mg Cr/ kg diet individually and/or the combined effect of those.

In this experiment, the improvement in growth parameters in supplemented treatments may be due to the enhance of feed efficiency which, reflected the extended duration of digestion and so long passage time of feed in the digestive tract. That allows Vit.+Min. to play the primary role in improving enzymes, physiological state, metabolism, and growth.

Serum biochemistry indices

Serum blood parameters are significantly affected by FR under summer conditions (HS). Restricted feeding significantly increased total protein, however clearly decreased glucose, creatinine, uric acid, triglycerides, and total cholesterol. These results are in line with those of Boostani et al (2010), reported that, FR increased total protein

and decreased glucose and cholesterol. Also, FR for 5 h between 22-56 days of age decreased cholesterol compared with ad libitum broilers (Barbour et al 2010). But these findings differ with, Farghly et al (2018) found that restriction (by timing feeding) under HS did not influence the values of serum total protein, glucose and cholesterol compared with chicks which fed ad libitum. In addition, applying quantitative FR for broilers did not have any effect on uric acid, creatinine, and glucose, however, reduced cholesterol values of serum blood (Rajman et al 2006).

The significant differences between control and FR treatments may be due to the considerable role of FR in growth and feed efficiency. Whereas mitochondrial function and biochemistry are wholly linked to feeding efficiency and growth performance in broilers, meanwhile mitochondria are responsible for producing 90% of the energy required for cells (Bottje et al 2006, Yang et al 2010).

As observed, restricted broilers under HS had the lower values of serum glucose compared with broilers in the control group; this decrease may be attributed to the reduction in FI accordingly a decrease in carbohydrate consumption and the hepatic storage of glycogen that are the available sources of energy. The cycle of glucose metabolism is one of the essential goals under HS (Faisal et al 2008). While hyperglycemia attributed to HS (Zulkifli et al 2000). In contrast, Klasing (1998) showed that restricted chicks maintain a constant glucose level, while restricted broilers can be able to synthesize glucose via gluconeogenesis. In addition, the reduction in serum triglycerides, it could be due to applying FR that directed to the obligate use of significant levels of triglycerides for energy demand (Demir et al 2004).

In this study dietary supplements (Vit.+Min.) to stressed broilers markedly improved total serum protein and declined serum glucose, creatinine, uric acid, triglycerides, and total cholesterol. These results are following Haq et al (2018) who noted that supplemental 250 mg Vit.C+0.5 mg Cr or 250 mg Vit.E+0.5 mg Cr/kg diet of broilers significantly decreased glucose, triglycerides, and total cholesterol. Additionally, supplementation with 250 mg Vit.E+250 mg Vit.C or 0.5 mg Cr per kg diet resulted in an increased serum total protein, but reduced serum glucose and cholesterol under high temperatures in summer conditions (Tawfeek et al 2014). In contrast, Ismail et al (2013) conducted that, stressed broilers (39±2 °C) fed on diets with 1000 mg Vit.C+ 100 mg Zn/kg diet did not affect serum total protein, glucose, uric acid, creatinine, triglycerides, and cholesterol. While, supplemental 200 mg Vit.C+100 mg Vit.E/kg diet of chicks did not differ total serum protein, glucose, and cholesterol under HS (Attia et al 2017).

From results of this study, it can be noticed that chicks in T7 (supplemental 200 mg Vit.C, 200, 200 mg Vit.E, 1.5 mg Cr, and 100 mg Zn) recorded marked increase in total serum protein than those in the other treatments, these results may be

due to chicks of the high BW show significantly increased in serum total protein (Faisal et al 2008). It could be as a result of the individual effect of Vit.C, Vit.E, Zn, and Cr and/or the combined effect of them. While Vit.C has protective functions on pancreatic tissues under HS (oxidative stress), it may improve pancreas functions to work correctly, hence enhancing the digestibility of nutrients (Khan et al 2012). Vit.E has the antioxidant impact on broilers by improving in the secretion of the growth hormones, feed efficiency, digestion, the hepatic, and lipid profile that reflected on blood parameters (Rehman et al 2018). Zn plays an essential role in various enzymatic activities by improving the digestion and absorption of nutrients (Naz et al 2016). In addition, the positive impacts of Cr on growth performance and blood parameters have been connected to chromodulins ability to improve the sensitivity of tissue receptors to insulin (Vincent 2000). Cr participation in the metabolism of carbohydrate including glucose (uptake and utilization) for lipogenesis and glycogen production (Haq et al 2016).

Carcass traits

Restriction improved carcass and reduced abdominal fat yields, however, did not influence liver and spleen yields except FR for 4 h (T4) increased spleen yield. These findings agreed with Shamma et al (2014) showed that FR for 4 and 6 h daily (for 1, 2, and 3 weeks of age) statically decreased abdominal fat and did not change values of liver yield under HS conditions. Also, restricted boilers by a reduction 25-50% in daily FI at growing periods (7-14, and 14-21 days) had higher carcass weight but did not differ spleen yield (Jahanpour et al 2015). In contrast, Azis et al (2019) showed that applying FR for 8 or 12 h (1-21 and 22-35days) had no effect on the carcass, abdominal fat but, increased liver yield. **Table 7** Carcass traits of broilers as affected by feed restriction (FR) and dietary supplementation with vitamins (C, E) and minerals (Cr, Zn) under summer conditions.

Treatments	Carcass yield (%)	Liver (%)	Spleen (%)	Abdominal fat (%)
T1 (control)	70.41 ^d	2.46	0.09 ^c	1.78 ^a
T2	71.33 ^c	2.46	0.10 ^{abc}	1.67 ^{ab}
T3	71.61 ^{bc}	2.37	0.10 ^{abc}	1.59 ^b
T4	72.45 ^a	2.42	0.11 ^{ab}	1.28 ^c
T5	71.32 ^c	2.45	0.09 ^{bc}	1.71 ^{ab}
T6	72.10 ^{ab}	2.45	0.10 ^{abc}	1.56 ^b
T7	72.73 ^a	2.46	0.11 ^a	1.25 ^c
SEM	0.21	0.06	0.01	0.01
Significance	**	NS	**	**

a,b,c, d – means with different letters in the same column are significantly different at (P<0.05). *, ** indicates significant at P<0.05, P<0.01 respectively. SEM, standard error of the mean. NS, not significant.

As observed, restricted feeding decreased serum total cholesterol and triglycerides that resulted in a decline in abdominal fat under summer conditions. In this regard, Faisal et al (2008) showed that a decrease in plasma lipid profile of restricted broilers could be due to a reduction in FI consequently, lower intake of energy, carbohydrates, and fat that led to fat depletion.

Supplemental Vit+Min (T6, T7) enhanced carcass and abdominal yields, in addition, broilers in T7 had higher spleen yield compared with broilers in the control group. These results of this study are totally consistent with Hag et al (2018) who found that adding Vit.C+Cr or Vit.E+Cr to broiler diets, enhanced carcass traits by increased dressing percentage and decreased abdominal fat, however, did not differ liver yield. In opposition, dietary supplementation with Vit.C+Vit.E for stressed broilers (36±2°C, 75–85% RH) did not affect carcass, liver, and abdominal fat yields (Attia et al 2017). The improvement of carcass traits (carcass, abdominal fat yields) by the combination of Vit.C, Vit.E, Cr and Zn, it could be due to the individual effect of each and/or the combined effect of them.

Conclusions

The results of this study suggested that applying FR for 3 h (T3) or dietary supplementation with 200 mg Vit.C+200 mg Vit.E+ 1.5 mg Cr +100 mg Zn /kg diet (T7) for stressed broilers (in open-sided housing under summer conditions), it can be significantly alleviating HS effects by improved performance parameters, safety, serum blood biochemistry, carcass yield and carcass quality (decreased abdominal fat yield). In addition, FR 4 h daily achieved good results under HS but may result in declined BW, which led to a longer growing period and delay in marketing age.

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