EFFECT OF EARLY HEAT EXPOSURE ON PHYSIOLOGICAL RESPONSES AND PRODUCTIVE PERFORMANCE OF BROILERS

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Abstract

This study was carried out at the Poultry Research Farm, Animal production Department, Faculty of Agriculture, Cairo University. The study aimed to investigate the effects of early heat stress on physiological and productive performance of broiler chickens. A total of 235 days old commercial Arbor-Acres broiler chicks were divided into 3 groups. Birds of 1st and 2nd groups were exposed early to heat stress (EHE) where; 1st group: 71, 3 days old chicks were exposed to heat stress at (42-43°C) for 4 h. 2nd group: 96, 5 days old chicks were exposed to heat stress at (42-43°C) for 4 h. 3rd group: 68 chicks were kept at normal brooding temperature (control). At 8 weeks of age, 30 birds from each of the three mentioned groups (90 chicks) were exposed to heat stress (heat challenged) at 42-43°C for 3 h.

Physiological responses (rectal temperature, respiration rate, protein and fat) were studied. Performance of chicks (body weight, growth rate, mortality rate) was recorded and chemical carcass contents were estimated (protein, fat, water and ash contents). The lowest and highest values of rectal temperature and respiration rate, respectively, were recorded in EHE at 3 days of age. Before heat challenge at 8 weeks of age, birds acclimatized at 3 days had the highest total plasma protein, albumin and globulin concentrations. Heat acclimatization at 3 days resulted in significant decrease in broilers sodium while plasma potassium significantly increased in 3 or 5 days acclimatization group at 8 weeks of age. Birds of the control group had significantly higher plasma total lipids.

Heat acclimatization at 3 days caused a significant increase in body weight at all ages (from 1 to 8 weeks of age). The average daily gain between 1-8 weeks of age showed that birds of EHE at 3 days had significantly the highest average gain. Growth rate from 1-8 weeks of age was significantly higher in 3 days of EHE group. Heat acclimatization at 3 days of age followed by heat stress at 8 weeks of age resulted in reduced water, fat and ash content of carcass meat, while, protein was increased. EHE at 3 and 5 days of age decreased the mortality rate during the experimental period and during heat challenge at 8 weeks of age.

INTRODUCTION

Broiler stocks bred for high growth rate and meat yield in optimal environments are not able to fully express this genetic potential when reared in hot climates unless they are subjected to the same sort of heat tolerance trails (Berrong and Washburn, 1998 and Abd El-Mutaal, 2003). Thermotolerance at an advanced age can be improved by a conditioning procedure that consists of exposing chicks during their 1st week of life (at 3, 5, or 7 days) to heat stress (Yahav and Hurwitz, 1996, Zhou *et al.,* 1997, and Yahav and McMurtry, 2001). During the process of acclimatization to heat stress, several systems that participate in thermoregulation modify their function to be adapted to these severe conditions.

Thermoregulatory and endocrine controlling centers in the hypothalamus are activated to permit the organism for reacting to environmental changes. Consequently, respiratory, vascular, and digestive systems are drawn to function resulting in changes in thermal reaction (body temperature and respiration rate) and metabolic reactions and blood contents (metabolites) (Yahav and Hurwitz, 1996, Ahmed *et al.,* 1998, Yahav and McMurtry, 2001, and Soliman, 2003). All these serial changes affect performance of chickens (Ain Baziz *et al.,* 1996), carcass quality and chemical composition (Gersaert *et al.,* 1996) and mortality rate (Yahav and Plavnik, 1999). Thus, the objectives of this work were:

1. To determine the optimal age of broilers for early heat exposure as a process of heat acclimatization for high ambient temperature.
2. To study the physiological responses and productive performance associated with the process of acclimatization to heat stress.

MATERIALS AND METHODS

This work was carried out in the Poultry Research Farm, Faculty of Agriculture, Cairo University, from September until November, 2000. A total of 235 one day-old commercial broiler chicks (Arbor-Acres) were used in this study. Chicks were individually weighed, wing banded, and raised under commercial management practice.

The brooding temperature was maintained between 34°C and 32°C and gradually decreased every 2 to 3 days to reach 24°±1°C until the end of the growing period. Chicks consumed starter ration containing 22% protein and 2890 Kcal ME/Kg diet during the first 4 weeks of age, followed by a grower ration containing 20% protein and 2900 Kcal ME/Kg diet during the period from 5 weeks to the end of the experiment (8 weeks). Chicks were vaccinated against New Castle disease and

Gomboro disease twice. Body weight and mortality rate were recorded weekly during the experimental period.

Chicks were divided into three groups, 71 chicks in the 1st group were exposed to high ambient temperature (42°-43°C) for 4hrs at 3 days of age in controlled temperature pens using electrical heaters. In the 2nd group, 96 chicks were subjected to the same temperature (42°-43°C) for 4h at 5 days of age. In the 3rd group, 68 chicks were kept as control group. At 8 weeks of age, a total of 90 birds (30 birds of each group) were exposed to heat stress (42°-43°C) for 3h.

At 8 weeks of age, thermal reactions were studied; rectal temperature (RT) and respiration rate (RR), blood samples were collected from the wing vein into heparinized tube and centrifuged immediately at 3000 rpm for 10 minutes. Plasma samples were stored in a deep freezer at -20°C. Total protein and albumin (g/dl) in plasma were determined using commercial kits. Plasma globulin was calculated using the difference between total protein and albumin. Total lipids (g/dl), sodium (meq/L) and potassium (mmol/L) concentrations in plasma were also determined using kits.

Body weight was recorded every week and daily gain was calculated biweekly. Growth rate was calculated biweekly throughout the experimental periods according to the following formula (Brody, 1945): Growth rate (%) = $(w_2 - w_1) / \frac{1}{2}(w_1 + w_2) \times 100$, where w_1 = Body weight at the beginning of the period and w_2 = Body weight at the end of the same period.

Mortality rate was daily recorded through the experiment. Also, mortality rate at 8 weeks of age (during heat exposure) was recorded. Chemical composition of carcass (breast and thigh) was determined.

Data were analyzed by the least square analysis of variance using the general linear model procedure (SAS, 1998). Duncan multiple range tests (1955) were used to test the level of significance among the means (Duncan, 1955).

RESULTS AND DISCUSSION

A. Physiological responses

At 8 weeks of age, birds exposed to heat stress (42°- 43°C) at 3 days of age (early heat exposure) for 4h, had the lowest rectal temperature followed by birds exposed to the same heat conditions at 5 days of age and birds in control groups, respectively (Table 1). The differences in rectal temperature between control and early heat exposure (EHE) groups were significant ($p \leq 0.05$). Similar results were obtained by Yahav and McMurtry (2001) where they found that the 3 days age is the best age of thermal conditioning. Significant lower rectal temperature of acclimatization than un-acclimated broilers during heat stress (heat challenge) was also reported by Yahav and Hurwitz (1996), Zhou *et al.,* (1997), Yahav and Plavnik (1999) and Abd El-Mutaal (2003).

The technique of temperature conditioning takes the advantage of the immaturity of the mechanism of temperature regulating center in the hypothalamus in young chicks during the first week of life. Borady *et al.,* (1979) reported that during the process of acclimatization to heat stress, many systems modify their functions to be adapted to these severe conditions. It is quite obvious from our results and the previously reviewed investigations that acclimatizea broilers have the capacity to stabilize their rectal temperature above normal, indicating improvement in their thermotolerance. However, rectal temperature of un- acclimatized continued to rise (Yahav and McMurtry, 2001).

The highest respiration rate (RR) was achieved in broilers when thermal conditioning had been applied at the age of 3 days (Table 1). Similar findings were reported by Zhou *et al.,* (1997). They found that broiler chicks acclimatized early in life (at 5 days of age) to 38°C for 24h when challenged to 33°C at 57 days of age for 3h, their RR was higher than non-acclimated chicks (control).

EHE chicks showed lower body temperature and higher RR than those non-acclimatized chicks. These results are in harmony with those of Teeter *et al.,* (1992) and Zhou *et al.,* (1997), who stated that acclimatized chickens have a lower heat production and body temperature and higher panting rates when subsequently subjected to high environmental temperature. Thermal panting is the major thermoregulatory mechanism responsible for maintaining body temperature of hyperthermic birds (Richards, 1976). The rate of which the fowl could increase its RR during hyperthermia defines its resistance to heat stress. The results of the present study indicated that acclimatized broilers had the ability to increase their RR. Zhou *et al.,* (1997) reported that prior exposure to high temperature can increase the ability to cope with subsequent heat load. Heat exposure to 42° C -43°C for 3h at 8 weeks of age (challenge period) resulted in significant ($p \leq 0.05$) decrease in plasma total protein of birds conditioned early at 5 days of age and non- acclimatized broilers (Figure 1).

Values of total protein levels in plasma in the present study were consistent with the findings of Ahmed *et al.* (1998) in Arbor-Acres broiler chickens. It was 3.29 g/dl at Egyptian hot summer conditions (33.5°C) and 30.54 g/dl in winter. Control birds showed lower albumin level in plasma compared with that of birds conditioned early in life at 3 and 5 days of age (Figure 2).

Early heat exposure (EHE) at 3 days of age showed the highest plasma globulin level after heat challenge (Figure 3). However, significant ($p \leq 0.05$) decrease in plasma globulin was observed in the control birds and early exposed chicks (at 5 days of age). Results of the present study are in agreement with Ahmed *et al.* (1998) who found significant ($p \leq 0.05$) lower plasma albumin in Arbor-Acres broilers reared under hot summer conditions than that of birds bred in winter.

Early heat exposure (at 3 or 5 days of age) in broilers resulted in lower plasma total lipids concentrations (at 8 weeks of age) than those in broilers of the control group (Figure 4). However, the differences were not significant. Our results are similar to the findings of Soliman (2003). He found that, exposure of 28 days age Norfa chickens to different temperatures (40°C and 45°C) for one hour 3 times weekly over 8 months resulted in a significant decrease in their plasma total lipids (399.29 and 405.00 mg), respectively compared to the control birds (451.3 mg).

Heat challenge at 8 weeks of age caused a non-significant decrease in plasma sodium levels of the control group (Figure 5). The reduction in plasma sodium level of broilers in the control group was about 10 and 5 meq/L than that of broilers exposed to heat at 3 and 5 days of age, respectively. Similar trend was observed in plasma potassium level due to EHE. There was a tendency to increased plasma potassium level of 8 weeks broilers after heat stress at 42°-43°C for 3h in birds exposed to heat at 3 or 5 days of age (Fig. 6).

Results indicated that plasma Na^{++} and K^{+} concentrations were affected by temperature, age and times of exposure. EHE at 3 or 5 days of age resulted in an increase in plasma sodium and potassium concentrations when birds were exposed later to heat ambient temperature at 8 weeks of age. Pardue *et al.* (1985) recorded a significant decrease ($p \leq 0.05$) in plasma K^{+} levels after exposure of 4 weeks old broiler chickens to 30 minutes.

B. **Productive performance**

Body weight of all groups was characterized by an increase during the first 4 weeks of age, followed by sharp linear increase during the period from the 4th to the 8th week of age. Body weight of EHE broilers (at 3 and 5 days) was significantly higher ($p \leq 0.05$) than that of control birds from 4 up to 8 weeks of age (Figure 7). At 8 weeks of age, EHE birds at 3 days showed the highest significant body weight (2167 g), while the control group recorded the lowest body weight (1873 g). Results are in agreement with, the findings of Yahav and McMurtry (2001) and Abdel Mutaal (2003). They found that chicks that had been thermally conditioned at high ambient temperature (37.5-43°C) at the age of 3 days recorded the highest body weight at 8 weeks of age.

Daily gain of EHE birds at 3 days of age had the highest non significant gain at the different ages followed by EHE birds at 5 days of age and control group, respectively (Figure 8). During the period from the 3rd to the 5th week of age, birds of EHE at 5 days of age recorded significantly ($p \leq 0.05$) the highest growth rate (90.66), followed by 3 days EHE birds (86.55) while, the control group had the least growth rate (78.44) (Figure 9). Also, during the period from 5-7 weeks of age, the highest growth rate was observed in EHE birds exposed at 3 days of age (50.66), whereas EHE at 5 days and control birds had low and almost the same values (48.46 and 48.57), respectively (Fig.9).

Results of the present study, which revealed the negative impact of late heat stress on body weight, daily gain and growth rate of broilers in control group, are in agreement with the reports of early and recent investigations (Yahav and McMurtry, 2001 and Abd El-Motaal, 2003).

Results indicated that broilers of EHE (3 or 5 days) had significantly ($p \leq 0.05$) lower mortality rate during the experimental period (Figure 10). Mortality rate of EHE birds was about 4% vs. 18% in birds of the control group. When birds of all three groups were exposed to heat challenge at 8 weeks of age (43°C for 3h), mortality rate of broilers in control group (Figure 11) was significantly ($p \leq 0.05$) higher by about 23% and 17% than that in EHE birds at 3 days of age and 5 days, respectively. These results are almost consistent with mortality rates exhibited in the study of Yahav and Hurwitz (1996), in which mortality during the thermal challenge to acute heat stress 35±1°C for 6h at the age of 42 days was significantly lower (21%) in birds heat conditioned at the age of 5 days than both conditioned at 7 days (24%) and control unconditioned birds (36%). May and Lott (2000) suggested that mortality is the best indicator for the effect of rearing temperature on performance.

There was a tendency to higher level of protein in the breast and thigh of EHE broilers at 3 and 5 days of age than those of control birds. A reverse effect was found for fat content, which was higher in carcass of control group than that in EHE groups (3 days and 5 days of age). However, there were no significant differences between groups in water content of carcass.

Regardless the effect of treatments, breast contained lower moisture percentage (3.07), higher protein (72.6), lower fat (19.6) and higher ash (4.63) contents than that in thigh, where moisture, protein, fat and ash percentages were

61.2, 28.6, and 3.00%, respectively (Table 2). Results declared that carcass fat content was decreased due to heat acclimatization at 3 or 5 days of age. Increased fattening due to heat stress was recorded by Geraert *et al.* (1996).

Conclusion

Results revealed that, thermotolerance for broilers at an advanced age can be improved by a conditioning procedure that consists of short term heat exposing post hatch (3 or 5 days old). This conclusion is in accordance with that of Yahav and McMurtry (2001). In addition we may conclude that 3days are the optimal age for broiler thermal acclimatization. Such acclimatized birds showed increased heat tolerance and improved their performance when exposed to heat challenge later in life at 8 weeks of age before marketing. We can conclude that thermal conditioning at 3 days of age is the most suitable regimen for the improvement of broilers thermotolerance and the avoidance of deleterious effect of hot waves which may happen during the last weeks before marketing (from 6 to 8 weeks of age).

Table 1. Rectal temperature (RT) and Respiration Rate (RR) of broilers at 8 weeks of age as affected by early heat exposure (EHE).

Treatments	RT (°C)	RR (no./second)
Control	41.60 ± 0.12^a	59.40 ± 0.89^b
EHE(3 days)	40.64 ± 0.12^b	63.20 ± 0.89^a
EHE (5 days)	40.85 ± 0.12^b	61.60 ± 0.89^a

means within traits having different superscripts differ significantly ($p<0.05$).
EHE: Chicks exposed to heat stress (42-43°C) for 4hrs at 3 days or at 5 days of age (early heat exposure).

Table 2. Effect of heat stress (42°-43°C) for 3hrs on breast and thigh chemical composition (%) of Arbor-Acres broilers at 8 weeks of age

Item	Groups		
	Control	EHE (3 days age	EHE (5 days age)
Breast			
Water	3.09^a	2.93^a	3.27^a
Protein	68.93^a	74.88^a	74.10^a
Fat	23.08^a	18.13^a	17.60^a
Ash	4.90^a	4.06^b	4.93^{ab}
Thigh			
Water	3.88^a	3.30^{ab}	3.27^b
Protein	60.12^a	68.09^a	65.50^a
Fat	32.27^a	25.06^a	27.50^a
Ash	3.73^a	3.55^a	3.73^a

means within traits having different superscripts differ significantly ($p<0.05$).
EHE: Chicks exposed to heat stress (42-43°C) for 4hrs at 3 days or at 5 days of age (early heat exposure).

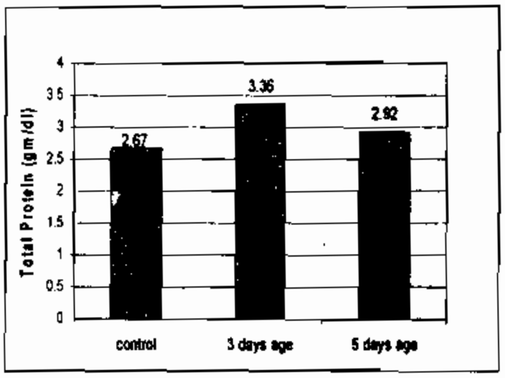

Fig. 1. Effect of early heat exposure (EHE) on plasma albumin of Arbor-Acres broilers at 8 weeks of age

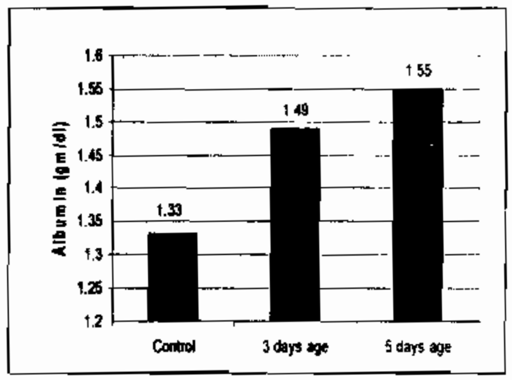

Fig. 2. Effect of early heat exposure (EHE) on plasma total protein of Arbor-Acres broilers at 8 weeks of age

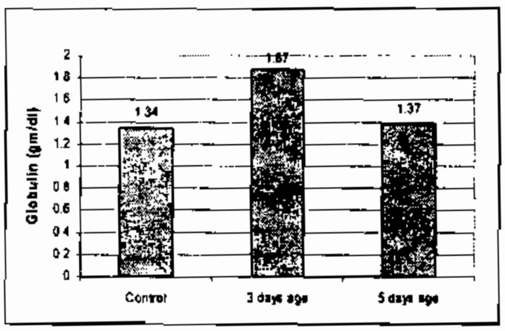

Fig. 3. Effect of early heat exposure on plasma total lipids of Arbor-Acres broilers at 8 weeks of age

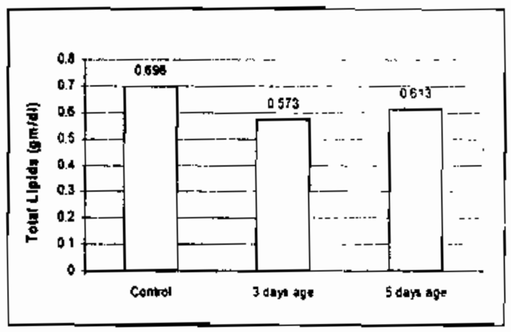

Fig.4. Effect of early heat exposure on plasma globulin of Arbor-Acres broilers at 8 weeks of age

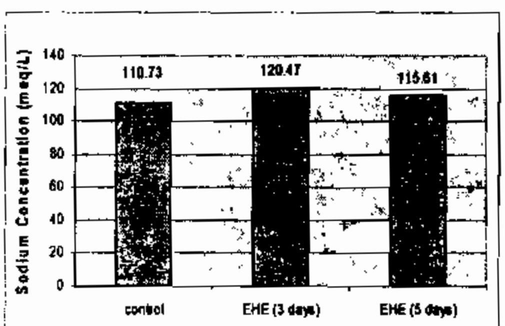

Fig. 5. Effect of early heat exposure (EHE) on plasma potassium concentration of broilers at 8 weeks of age

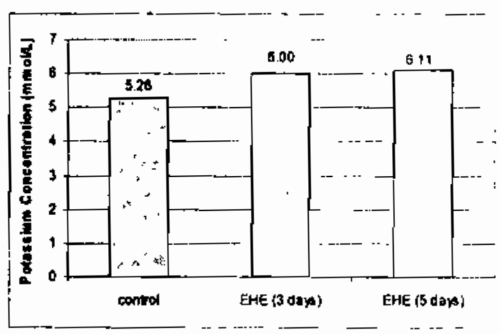

Fig.6. Effect of early heat posure (EHE) on plasma sodium concentration of broilers at 8 eeks of age

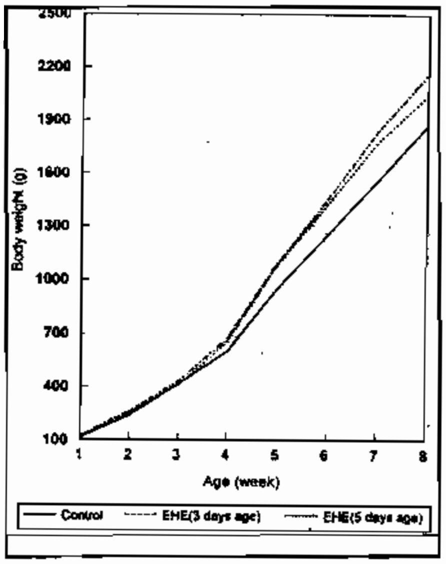

Fig. 7. Effect of early heat exposure (EHE) on daily gain (biweekly) of broilers at 8 weeks of age

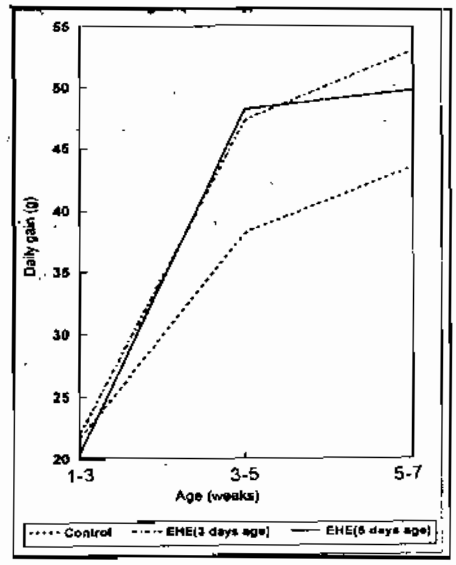

Fig. 8. Effect of early heat exposure (EHE) on body weight (g) of broilers at 8 weeks of age.

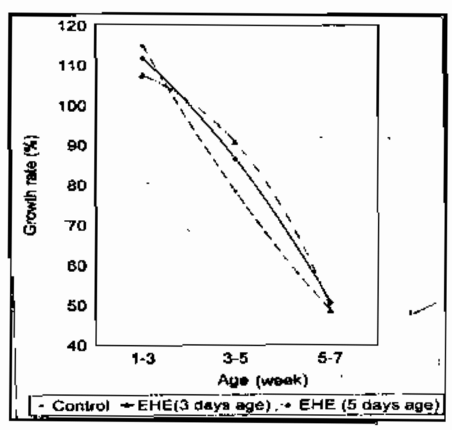

Figure 9. Effect of early heat exposure (EHE) on growth rate (%) of broilers at 8 weeks of age.

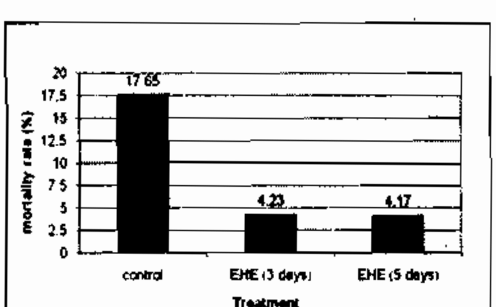

Fig. 11. Effect of early heat exposure (EHE) for 3hrs (42-43°C for 3hrs) at 8 weeks age on mortality rate

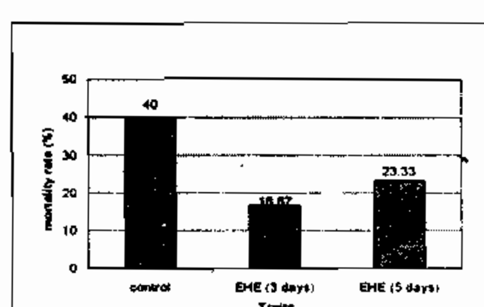

Fig. 10. Effect of early heat exposure (EHE) for 42-43°C on mortality rate (%) of Arbor-Acres broilers through 8 weeks.

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تأثير التعريض الحراري المبكر على الاستجابة الفسيولوجية و الأداء الإنتاجي لدجاج اللحم

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أجريت هذه التجربة بمزرعة أبحاث الدواجن- قسم الإنتاج الحيواني ، كلية الزراعة- جامعة القاهرة. و كان الهدف هو دراسة تأثير التعريض المبكر للحرارة على الاستجابة الفسيولوجية و الأداء الإنتاجي لدجاج التسمين. أجريت هذه الدراسة على ٢٣٥ كتكوت تسمين (اربور ايكرز) عمر يوم قسمت إلى ثلاث مجاميع كالأتي: في المجموعة الأولى تم تعريض ٧١ كتكوت عمر ثلاثة أيام لدرجة حرارة ٤٢- ٤٣°م لمدة ٤ ساعات، في المجموعة الثانية تم تعريض ٩٦ كتكوت عمر ٥ أيام لدرجة حرارة ٤٢- ٤٣°م لمدة ٤ ساعات، أما المجموعة الثالثة فيها عدد ٦٨ كتكوت كنترول (تحت ظروف التحضين العادية). على عمر ٨ أسابيع تم تعريض ٣٠ طائر من كل مجموعة (٩٠ طائر) لدرجة حرارة ٤٢- ٤٣°م لمدة ثلاث ساعات.

تم دراسة الاستجابة الفسيولوجية (درجة حرارة الجسم- معدل التنفس- بروتينات و دهون الدم- نسبة الصوديوم و البوتاسيوم في الدم) كما تم تسجيل الأداء الإنتاجي (وزن الجسم- معدل النمو- معدل النفوق) و تم تقدير المكونات الكيميائية للذبيحة (البروتين- الدهون- الرماد- المحتوى المائي).و كانت أهم النتائج كالأتى:

درجة حرارة الطيور التي تعرضت للحرارة على عمر ثلاثة أيام كانت أقل معنويا عن الطيور في المجاميع الأخرى. كما تم الحصول علي أعلى معدل تنفس معنويا في الطيور التي تعرضت مبكرا للحرارة على نفس العمر. لوحظت أعلى نسبة بروتين في البلازما في المجموعة التي تعرضت على عمر ثلاثة أيام وكذلك نسبة الألبيومين و الجلوبيولين. كما انخفضت نسبة الصوديوم و ارتفعت نسبة البوتاسيوم في البلازما معنويا بعد التعريض الحراري علي عمر ٨ أسابيع. لوحظت أعلي نسبة لدهون البلازما في مجموعة الكنترول.

إزداد وزن الجسم معنويا في المجموعة الأولي (تعريض حراري علي عمر ٣ أيام) في كل الأعمار (من ١ إلي ٨ أسابيع) عن المجموعتين الثانية و الثالثة. كما ارتفع متوسط الزيادة اليومية معنويا في نفس المجموعة. ارتفع معدل النمو معنويا في المجموعة الأولي (تعريض حراري علي عمر ٣ أيام) عن المجموعتين الثانية و الثالثة. احتوت مكونات الذبيحة في المجموعة الأولي (تعريض حراري علي عمر ٣ أيام) علي أقل نسبة من الماء و الدهن و الرماد بينما إزدادت بها نسبة البروتين. كما أظهرت النتائج أن تعريض الطيور للحرارة علي عمر مبكر (٣ أو ٥ أيام) أدى إلي انخفاض معدل النفوق معنويا.