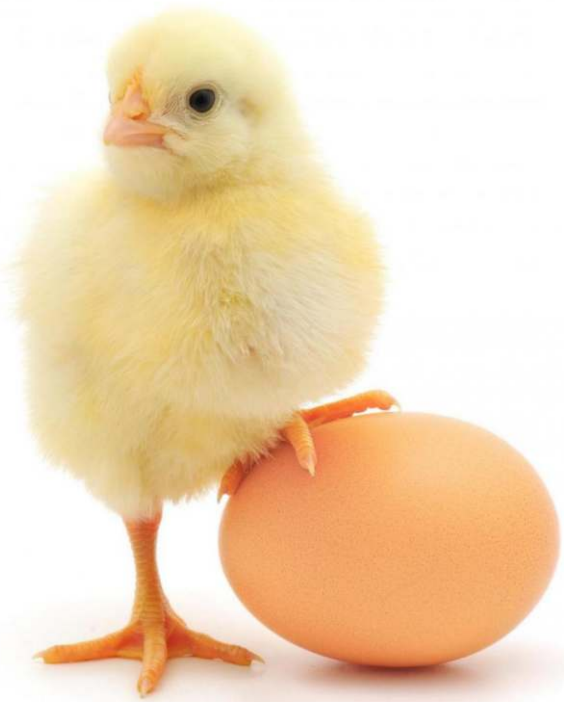
ISSN 1682-8356
ansinet.org/ijps



INTERNATIONAL JOURNAL OF POULTRY SCIENCE

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International Journal of Poultry Science 5 (2): 185-190, 2006
ISSN 1682-8356

Effect of Chronic Heat Stress and Long-Term Feed Restriction on Broiler Performance

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Abstract: An experiment was conducted to investigate the effects of long-term feed restriction on alleviating the effects of chronic heat stress on the performance of 4-8-wk old *ISA Vedette* broiler birds. Environmental temperatures were constant 25, and 35±2°C in controlled environmental rooms and variable-natural temperature ranged between 21 and 30±2°C in an open-sided poultry house. At 4 weeks of age, Daily feed consumption in all experimental rooms was restricted to 75% and 50% of the daily *ad libitum* consumption recommended in the management guide for this strain. At the end of experiment, a representative sample of 8-wk-old broilers from each treatment was selected and placed randomly in controlled-environmental chambers set at 40±1°C for heat tolerance test. The results showed that, rearing temperature of 35±2°C in closed environment and variable-natural temperature of 21-30 ± 2°C in the open-sided environment had a significant ($p<0.05$) negatively effects on broiler performance. Long-term feed restriction to 75% or 50% reduced significantly ($p<0.05$) the growth rate and body gain of 4-8-wk old broilers. The body weight gain of birds reared at 35°C and fed 50% of *ad libitum* was higher than their counterparts reared at constant 25°C or variable-natural temperature (21-30°C). Feed conversion ratio and survivability were significantly ($p< 0.05$) improved with increasing feed restriction at high ambient temperature of 35±°C. However, feed restriction at lower ambient temperature of 25°C had negative effects on feed conversion ratio. On the other hand, heat tolerance test showed that, feed restriction improved heat tolerance and increased the heat resistance of 8-wk old broilers when exposed to 40°C. Lower mortality rate and lower rate of increase of rectal temperature of feed restricted birds indicated this. From the results of this experiment, it could be concluded that, ambient temperature and long-term feed restriction significantly affect broiler performance. Moreover, long-term feed restriction at high ambient temperature increase heat resistance and improve the heat tolerance of growing broilers, when exposed to heat waves in summer season.

Key words: Broiler performance, feed restriction, heat stress, heat tolerance

Introduction

The expression of heat stress in poultry production can be described as 'acute' or 'chronic'; acute heat stress refers to short and sudden periods of extremely high temperature, where as chronic heat stress refers to extended periods of elevated temperature (Emery, 2004). On the other hand, conditions of heat stress caused an increasing concern in poultry production due to the rapid development of poultry industry in hot-climate countries and to the reduced performance of poultry during summer months in temperate countries (Bonnet *et al.*, 1997). It has been shown that heat stress has detrimental effects on the performance of 4-8 wk old broiler birds reared in the open-sided poultry houses; principally through reducing feed intake, growth rate, negatively affect feed efficiency and carcass quality as well as health (Carmen *et al.*, 1991; Yahav *et al.*, 1996; Temim *et al.*, 2000; Har *et al.*, 2000; Oskan *et al.*, 2003). Moreover, chronic heat stress increases the time to reach market weight and increase mortality rate (Howlider and Rose, 1989; Ozbey and Ozceilik, 2004).

Feed restriction during the periods of heat stress has become a common management practice in many broiler-producing areas (Koh and Macleod, 1999; Oskan *et al.*, 2003). Lowering feed intake can lower the body temperature of the heat-exposed broiler birds and increase its ability to survive acute heat stress (Li *et al.*, 1992; Wiernusz and Teeter, 1996; Koh and Macleod, 1999). Beneficial effects of short-term fasting on broiler performance prior to acute heat stress have been extensively reviewed. However, there is less information on the effects of long-term feed restriction on broilers reared under summer conditions that may impose chronic heat stress (Oskan *et al.*, 2003). In addition, most previous feed restriction-thermal environment studies were conducted under short-term fasting at cyclic or constant-acute heat stress conditions in closed environment neither explained nor compared the effects of variable-natural with constant-chronic high rearing temperatures on broiler performance. Therefore, the objectives of this study were to investigate the effects of long-term feed restriction on alleviating the effects of constant-chronic heat stress and variable-natural temperatures on the performance of 4-8 wk old broilers reared in closed and open-sided houses.

Materials and Methods

Experimental rooms

Controlled environmental rooms: A controlled environmental poultry house consists of 2 identical rooms was used in this study. Each room was divided into 6 identical pens measure 0.88 x 2.40 m. supplied with a trough feeder and automatic-cup drinker. Each room was equipped with thermostatically controlled electric heaters and an electric fan for the circulation of air. Air is removed from the rooms by the presence of one exhaust fan in the back area of the room. Relative humidity was uncontrolled inside the rooms, it was ranged between 36-50% during the experimental period. Continuous artificial light was used to illuminate the interior space during the experimental period, which was lasted four weeks.

Open-sided poultry house: An open-sided poultry house used contained 6 identical rooms. Each room was divided by a wire mesh into two equal pens measure 2.20 x 4.10 x 3.50-m. Each pen was supplied with a trough feeder and automatic cup drinker. Artificial light, during the night was used which was controlled by the automatic-clock timer switched on at 00190 hr and off at 0500 hr during the morning time. Environmental conditions inside the house were not controlled and thus varied with the outside natural conditions.

Controlled-environmental chambers: Two controlled environmental chambers were used for heat tolerance test of 8-wk old broilers at 40±1°C. The dimensions of the two chambers are 2.70 x 2.10 x 2.34 m and 1.80 x 2.40 x 2.34 m, respectively. Each chamber was equipped with thermostatically controlled electric heaters and an electric fan for the circulation of air. Two holes of 16-cm diameter in both sides of the chamber were made to provide ventilation. A battery of 8 individual cages arranged in two rows, were installed inside each chamber. Each cage measure 37x30x40 cm, and supplied with separate drinker and feeder. Ambient temperature can be controlled to the accuracy of 40±1°C.

Experiment: Six hundred *ISA Vedette* day-old broiler chicks were obtained from a commercial hatchery and reared from one day to 4 weeks of age as a group using the standard brooding practices. They were reared on litter with feed and water provided *ad libitum*. They were fed a standard starter diet from 0 to 4 weeks of age (Table 1).

At four weeks of age a total of 480 *ISA Vedette* growing broilers were weighed and moved at random to the experimental rooms. Three environmental temperatures were used, 25 ± 2°C, 35 ± 2°C with a relative humidity of 41-50 % in the controlled environmental rooms, and 21-30°C natural variable temperature, with a relative humidity of 36-42% in the open-sided poultry house. Broiler treatments in each temperature room were designed to restrict feed intake by restricting the amounts of feed that the birds were allowed to consume each day. Broilers in each room were fed *ad libitum*, 75, and 50% of the daily feed intake amounts recommended in the management guide for this strain (Institut de Selection Animale, ISA, 1989). Feed intake levels were adjusted to *ad libitum* amounts recommended in the management guide to make the comparison between the broiler feed treatments at different ambient temperatures is possible. The total amounts of feed intake offered to broilers at different ambient temperatures were 1782.5, 2674, and 3565, gram/bird for (50%AL), (75%AL), and *ad libitum* (AL) treatments, respectively (Institut de Selection Animale, ISA, 1989). Water was provided for *ad libitum* consumption. They were kept under experimental conditions throughout the experimental period from 4 to 8 weeks of broiler age.

The experimental treatments were 3 levels of feed x 3 environmental temperatures. There were 2 replicates of 20 birds each, in the controlled environmental rooms, and 2 replicates of 40 birds each, for each treatment in the open-sided rooms with 10 birds/m^2. All the means of experimental treatments were analyzed by ANOVA using the general linear model (GLM) procedure of statistical analysis system (SAS) (SAS Institute, 1987). When a significant *F* statistic was noted, treatment means were separated using Duncan's multiple range test. Statements of significant difference are based on of P = 0.05.

Heat tolerance test: This test was conducted to investigate the effects of rearing-ambient temperature and feed restriction regimes on the heat tolerance time and rate of increase of rectal temperature (RITr) of 8-week old broilers when exposed to acute heat stress of 40±1°C. At the end of the four weeks of the experiment, a representative sample of 8-wk old broilers was randomly selected from each treatment and moved to the environmental physiology lab where the two controlled environmental chambers set at 40 ±1°C. The broiler samples were marked and randomly placed into the chambers and kept at 40±1°C until the rectal temperature reached about 45°C or death occur. Rectal temperature of the broiler samples was measured before the beginning of the test and then at hourly intervals, or more frequently if approached 45°C, using an electric-thermocouple thermometer inserted approximately 3 cm accurate to 0.1°C (Yalcin *et al.*, 2001). No feed or water was offered during the test. The increasing rate of rectal temperature (RITr) during the test period was calculated by dividing the change of rectal temperature (°C) on the time period (hours) spent until rectal temperature reached 45°C or death occur. Sykes and Alfataftah (1987) used this expression as an indicator of heat tolerance improvement.

Table 1: Ingredients and calculated composition of the basal diets

Ingredients and composition	Starter (%)	Finisher (%)
Yellow Corn	63.80	72.20
Soy bean meal (44% CP)	28.00	21.50
Fish meal (72% CP)	5.00	3.00
Lime stone	1.60	1.60
Dicalcium phosphate	1.00	1.20
Premix (Vitamin + Minerals)	0.10	0.10
DL-Methionine	0.20	0.10
Sodium Chloride	0.30	0.30
Coccidiostat	0.05	0.05
Calculated Analysis		
Metabolizable Energy (kcal/kg)	2921	2994
Crude Protein%	21.40	18.10
Lysine%	1.19	0.93
Methionine%	0.55	0.33
Methionine and Cystine %	0.89	0.62
Calcium%	1.09	1.08
Total Phosphorus%	0.98	0.68

Rations: Standard broiler starter and finisher diets were fed from 0 to 4 and 5 to 8 weeks of age, respectively, are shown in Table 1. It supplies the required nutrients recommended in the management guide of ISA Vedette broiler strain used in this experiment (Institut de Selection Animale, ISA, 1989).

Results and Discussion

Broiler performance: Means±S.E of live performance parameters of broilers reared at different environmental temperatures and three feeding regimes are shown in Table 2. The body weight of broilers fed *ad libitum* and reared at 35, 25°C and natural (21-30°C) are significantly ($p < 0.05$) higher than their counterparts fed 50 or 75% of the ad *libitum* consumption. The results also showed that, feeding regime affected the body weight significantly ($p < 0.05$). At the end of the four weeks of the experiment, the body weight of broilers in all heat treatments decreased significantly ($p < 0.05$) as feeding regime reduced from *ad libitum* to 75% and 50% of the *ad libitum* consumption. Broilers fed *ad libitum* at the ambient temperature of 25°C had higher body weight than those at 21-30°C, but significantly ($p < 0.05$) higher than those reared at 35°C. This finding is consistent with the observations of Ozbey and Ozceilik (2004); Oskan *et al.* (2003) and AbuDieyeh (2006).

The increase in heat tolerance of birds by restricted feeding was clearly illustrated by the results obtained. The body weight of the birds reared at 35°C and fed 50% at the end of the four weeks of the experiment was 1375 gram versus 1334 gram for the birds reared at 25°C. This difference was significant at ($p < 0.05$) level, while restriction of feed to 75% had smaller effect on heat tolerance compared with 50% level. These results are in agreement with the results obtained by (Zulkifieli *et al.,* 1994; Hocking *et al.,* 1996; Koh and Macleod, 1999).

The trend in body weight gain was the same as the body weight as illustrated in Table 2. The body weight gain of birds reared at 35°C and fed *ad libitum* was significantly ($p<0.05$) lower than those reared at 25°C or 21-30°C when compared at the 4 weeks of experiment. However, feed restriction to 75% or 50% of *ad libitum* increased heat tolerance of birds reared at 35°C. Since, there were no significant differences in the total body gain when compared with their counterparts reared at 25°C. The body weight gains of birds reared at 35°C and fed 50 % or 75% of *ad libitum* were 784 and 1091 gram/bird respectively, versus 754.5 and 1161 of birds reared at 25°C. These results are in agreement with the results obtained by Koh and Macleod, (1999) who found that, the body weight of broilers reared at 32, 27, 22, and 17°C was decreased significantly with decreasing feed intake to 75, 50, and 25% of *ad libitum* consumption. In addition, Ouart *et al.* (1989) found that birds reared in hot environment (32°C) for 4.7 hour/day and fasted 10 hour/day had significantly ($p < 0.05$) lower body weight changes than those unheated and full fed *ad libitum* consumption.

Means ±S.E of feed conversion ratio of broilers reared at different ambient temperatures and fed different feeding regimes are shown in Table 2. The results show clearly the effect of increasing environmental temperatures on feed conversion ratio. Feed conversion ratio of birds reared at 35°C and fed *ad libitum* was significantly higher than those reared at 25°C and also higher than those at 21-30°C. In general, ad *libitum* fed birds reared in hot environment (35°C) achieved the poorest feed efficiency and they were less efficient in feed utilization than birds reared in lower ambient temperatures (25°C and natural 21-30°C). These results are similar to the findings of previous researchers (McDowell, 1972; Harris *et al.,* 1974; Yahav *et al.,* 1996; Ozbey and Ozceilik, 2004; Abu-Dieyeh, 2006).

Feed restriction had a positive effect on the feed conversion ratio of birds reared under hot environment (35°C) at the fourth week of the experiment. It was 2.27, 2.45, and 2.60 for birds fed 50%, 75% and *ad libitum,* respectively. This is a clear indication of improved heat tolerance of birds by feed restriction. However, feed restriction at lower ambient temperatures 25°C had negative effects on feed conversion ratio. In the open-sided room at natural variable temperature (21-30°C), there were significant ($p<0.05$) differences in the average feed conversion ratio of the *ad libitum* birds and those restricted to 75% of *ad libitum* consumption. Feed conversion ratio of feed-restricted birds was lower than the average feed conversion ratio of *ad libitum* birds. This finding is consistent with the observations of Plavnik and Yahav (1998).

The improvement in feed efficiency associated with feed restriction at 35°C has been attributed to higher metabolic efficiency associated with maintaining a smaller body weight. At the natural variable temperature

Table 2: Means ±S.E of live body weight, body gain, feed consumption, feed conversion ratio (FCR), and mortality rate of 8 wk-old broilers reared at different ambient temperatures and fed different feeding regimes

Performance parameter	Treatments								
	Variable-Natural Temperature (21-30°C)			Constant-Chronic Ambient Temperature 25°C			Constant-Chronic Ambient Temperature 35°C		
	Ad libitum (AL)	75% (AL)	50% (AL)	*Ad libitum* (AL)	75% (AL)	50% (AL)	*Ad libitum* (AL)	75% (AL)	50% (AL)
Live Body Weight (gram/bird)	$2050^{a}\pm21$	$1807.5^{c}\pm44$	$1321^{g}\pm 20$	$2107^{a}\pm 35$	$1755^{d}\pm 0.0$	$1334.5^{g}\pm38$	$1847.5^{b}\pm30$	$1716.5^{e}\pm5.0$	$1375^{f}\pm 0$
Live Body Gain (gram/bird)	$1358^{a}\pm 50$	$1218^{b}\pm 67$	$716.5^{c}\pm23$	$1544^{a}\pm19$	$1161^{b}\pm94$	$754.5^{c}\pm54$	$1178^{b}\pm43$	$1091.5^{b}\pm4.0$	$784^{c}\pm23$
Feed Consumption (gram/bird)	3535^{a}	2673^{d}	1784^{e}	3418^{b}	2673^{d}	1784^{e}	3042.5^{c}	2673^{d}	1784^{e}
Feed Conversion Ratio (FCR)	$2.59^{a}\pm.06$	$2.19^{bc}\pm.10$	$2.49^{abc}\pm.10$	$2.19^{c}\pm.02$	$2.29^{bc}\pm.02$	$2.32^{bc}\pm.20$	$2.60^{a}\pm.10$	$2.45^{abc}\pm.05$	$2.27^{bc}\pm.10$
Mortality Rate (%)	$3.62^{b}\pm3.0$	$2.22^{b}\pm0.0$	$1.11^{b}\pm1.0$	$0.00^{b}\pm0.0$	$0.00^{b}\pm0.0$	$5.13^{b}\pm5.0$	$12.9\,1^{a}\pm0.0$	$5.00^{b}\pm0.0$	$0.00^{b}\pm0.0$

Means with different superscripts in the same row are significantly different at ($p < 0.05$).

Table 3: Means ±S.E of rectal temperature (°C) of broilers reared at different ambient temperatures and fed different feeding regimes during the periods of experiment 2.

	Treatments								
Weeks	Variable-Natural Temperature (21-30°C)			Constant-Chronic Ambient Temperature 25°C			Constant-Chronic Ambient Temperature 35°C		
	Ad libitum (AL)	75%(AL)	50%(AL)	*Ad libitum* (AL)	75%(AL)	50%(AL)	*Ad libitum* (AL)	75%(AL)	50%(AL)
1	$40.90^{c}\pm0.0$	$41.05^{c}\pm0.1$	$40.6^{d}\pm0.2$	$40.85^{cd}\pm0.1$	$40.90^{c}\pm0.0$	$40.95^{c}\pm0.1$	$42.05^{a}\pm0.1$	$41.45^{b}\pm0.2$	$40.75^{cd}\pm0.2$
2	$41.\,00^{b}\pm0.2$	$40.\,9^{bc}\pm0.1$	$40.6^{de}\pm0.0$	$40.85^{bcd}\pm0.1$	$40.8\,5^{bcd}\pm0.1$	$40.7^{cde}\pm0.0$	$41.6^{a}\pm0.3$	$41.\,4^{a}\pm0.2$	$40.55^{e}\pm0.1$
3	$41.25^{b}\pm0.5$	$40.85^{c}\pm0.1$	$40.75^{cd}\pm0.1$	$40.8^{cd}\pm0.0$	$40.95^{c}\pm0.1$	$40.75^{cd}\pm0.1$	$42.25^{a}\pm0.2$	$41.45^{b}\pm0.2$	$40.55^{d}\pm0.1$
4	$41.0^{cd}\pm0.1$	$41.\,2^{bc}\pm0.2$	$40.80^{d}\pm0.1$	$41.05^{cd}\pm0.2$	$41.\,2^{bc}\pm0.1$	$40.8^{d}\pm0.1$	$41.95^{a}\pm0.1$	$41.35^{b}\pm0.1$	$40.8^{d}\pm.01$

Means with different superscripts in the same raw are significantly different at ($p< 0.05$).

Table 4: Means ±S.E mortality rate (%), and rate of increase of rectal temperature *RITr,* (°C/ hour) of 8-wk old broilers exposed to 40°C at the end of experiment.

	Rearing Ambient Temperatures (°C)								
	Variable-Natural Temperature (21-30 °C)			Constant-Chronic Ambient Temperature 25 °C			Constant-Chronic Ambient Temperature 35 °C		
Parameter measured	*Ad libitum* (AL)	75% (AL)	50% (AL)	*Ad libitum* (AL)	75% (AL)	50% (AL)	*Ad libitum* (AL)	75% (AL)	50% (AL)
Mortality rate (%)	$75^{ab}\pm19$	$25^{abc}\pm19$	$0.0^{c}19$	$88^{a}\pm19$	$50^{abc}\pm19$	$12^{bc}\pm19$	$13^{bc}\pm19$	$0.0^{c}\pm19$	$0.0^{c}\pm19$
RITr	$3.9^{a}\pm0.6$	$3.0^{a}\pm0.6$	$2.1^{a}\pm0.6$	$3.9^{a}\pm0.6$	$3.3^{a}\pm0.6$	$3.6^{a}\pm0.6$	$2.1^{a}\pm0.6$	$2.70^{a}\pm0.6$	$2.40^{a}\pm0.6$

Means with different superscripts in the same raw are significantly different at ($p<0.05$).

(21-30°C), the average feed conversion ratio of broilers restricted at 75% of *ad libitum* consumption is insignificantly lower than the corresponding groups reared at 25 and 35°C. In layer hens, Li *et al.* (1992) found that the rate of heat production decreased continuously with increasing environmental temperature at any feed consumption level. The decrease in heat production with increasing environmental temperature resulted in a reduction of energy requirements. The rates of change in heat production with temperature tend to increase with the reduction in feed consumption, which indicates that the optimal temperature for energy efficiency increases with decreasing feed consumption. Rearing broilers at high ambient temperatures (35°C) caused a significant increase in mortality rate as shown in Table 2. Feed restriction of broilers kept at high ambient temperature (35°C) reduced significantly the mortality rate. The total mortality rates at 35°C were 12.19, 5.0 and 0.0% for broilers fed *ad libitum,* 75 % and 50 %, respectively. The same trend was also illustrated for broilers reared at the natural treatment.

The reduction of mortality rate indicates that feed restriction reduces the effect of heat stress on broiler performance. Survivability was associated with lower feed consumption and body weight and was associated with lower metabolic heat production throughout the experimental period, which reduces the susceptibility to heat stress. The increase in heat tolerance might be due to a decrease in heat production as a result of feed consumption. (Li *et al.,* 1992; Wiernusz and Teeter, 1996). Lower rectal temperatures as shown in Table 3 indicate this. In general, feed restriction at 50 and 75% of *ad libitum* consumption was associated with a lower rectal temperature of broilers kept at the three ambient temperature treatments. This finding is consistent with the observations of Altan *et al.* (2003); Ozbey and Ozceilik (2004) and Abu-Dieyeh (2006).

The lower *Tr* at 35°C reflects the increase of heat tolerance of birds as a result of feed restriction. Thus, feed restriction from 75 to 50% of *ad libitum* improved significantly the heat tolerance of broilers particularly in the last weeks of rearing period. These results could be explained that feed restriction was associated with lower metabolic heat production which led to a reduction in heat load and subsequently *Tr* did not increase and was maintained within normal limits (North and Bell, 1990). This is a clear indication that feed restriction improved heat tolerance of broilers during exposure to chronic heat stress. This is confirmed by the results of Koh and Macleod (1999) who found that, rectal temperature of broilers was increased significantly when feed intake level was increased from 25, 50, 75% of *ad libitum* consumption.

Heat tolerance test: Means of mortality rate, and the rate of increase of rectal temperature (*RITr*) of broilers during the heat tolerance test at 40°C are shown in Table 4. The results illustrate the effect of rearing ambient temperature and feed restriction on improving heat tolerance of 8-week old broilers when exposed to ambient temperature higher than the rearing temperatures.

Feed restriction improved heat tolerance significantly, particularly at the 50 % level in the different heat treatments. The results illustrate the importance of feed restriction and rearing ambient temperature on reducing great losses during exposure to a heat wave. Also, increasing the heat tolerance was expressed in lower rate of increase of rectal temperature (*RITr). RITr* of broilers reared at 35°C was insignificantly lower than their counterparts reared at 25°C or natural (21-30°C). Also, feed restriction at 35°C resulted in lower rate of increase of rectal temperature, which is an indication of improved heat tolerance. This finding is consistent with the observations of Zulkifili *et al.* (2000) who found that, the survivability of female broilers restricted at an early age to 60% of *ad libitum* consumption was significantly ($p < 0.05$) higher than *ad libitum* broilers when exposed to heat tolerance test at 38°C.

These results indicated that the upper critical temperature could be increased at high rearing temperature and feed restriction. Carmen *et al.* (1991) found that, when birds were exposed for 4 hours to 38°C without feed had significantly ($p<0.05$) lower rate of increase of rectal temperature and the rectal temperature attained after 4 hours of heat exposure was 41.2°C compared with the control group exposed with available feed. This is due to prior heat acclimatization and lower heat production of the birds. Teeter and Smith (1986) reported that, at least 50% of the hyperthermic effect of acclimatization immediately prior to heat stress might be attributed to a reduction in feed intake in response to the stress. Heat acclimatization is brought about by a reduction in heat production rather than by an increase in heat loss. Moreover, Lott (1991) found that, acclimated broilers at 35°C had significantly ($p < 0.05$) lower rectal temperature than unacclimated birds received feed 1 hour prior to exposure at 24 - 41°C. This is confirmed by the results of Sykes and Alfataftah (1986) who found that, the failure to acclimatize following transfer of birds from a hot (30) to a cool (20) environment was due to an increase in feed intake and heat production.

Finally, it could be concluded from the all results of this experiment that, chronic heat stress and long-term feed restriction significantly affect broiler performance. Thus, full-fed broilers reared in open-sided environment during summer season need longer time than moderate conditions to achieve the same body weight. Subsequently, the market age will be longer. Moreover, Long-term feed restriction of heat stressed broilers is not only responsible for poor performance, but also, it increase heat resistance and improve the heat tolerance of growing broilers when exposed to heat waves during summer season.

Acknowledgments

The author wishes to thank the Deanship of Scientific Research Department in Al-Balqa Applied University for valuable support and advice.

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