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Effect of Short-term Water Restriction on Body Weight, Egg Production, and Immune Response of Local and Commercial Layers in the Late Phase of Production

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ABSTRACT : Forty-five Hisex commercial layers and forty-five local Saudi breed layers were used to determine the acceptable limit of short-term water restriction in the late phase of production, when the problem of high feed and water consumption is expected. The experiment was performed under hot and arid environmental conditions when the layers were at fifty weeks of age. Layers from each breed were randomly assigned in groups of five into nine floor pens. The average environmental temperature was 37.2-38.6°C, and the relative humidity was between 20 to 37%. The trial was divided into 3 periods; control (1 week), water restriction (2 weeks) and rehydration (1 week). During the restriction period, layers from each breed were divided into three groups that received 20, 40, and 0% restriction of drinking water relative to their consumed water during the control period. During the study, feed and water consumption, body weight, changes in body weight, egg production, primary antibody response to SRBC, and rectal temperature were evaluated. Water restriction did not result in any clear effect on feed intake in either breed, however, commercial layers tended to consume less feed compared to the local breed. Body weight declined with water restriction during the first week of restriction in the commercial breed regardless of rate of restriction, but it was delayed until the second week in the local breed. Water restriction of 40% decreased egg production in both breeds but with a delay of 1 week in the local breed. Antibody level to SRBC was not affected by water restriction in the commercial line while it was highly affected in the local breed. A water restriction of 20% is considered to be an acceptable limit under the current experimental conditions without a negative effect on egg production in both breeds and considering the immune status of the local breed. Whereas, 40% restriction had a negative effect on egg production, and varied effects in the other traits in both breeds.
(**Key Words :** Water Restriction, Body Weight, Egg Production, Immune Response)

INTRODUCTION

Water is considered to be a fundamental nutrient to every living animal and its attainability is considered to be a crucial element for sustained performance in productive animals. Therefore, any limited water supply would inevitably disrupt the productive process in domestic chickens. When domestic chickens face a term of a limited water supply that consequently resulted in lower body water losses by adjustments of the pattern loss from various body water compartments. Accordingly, vital physiological systems are least impaired. During hot season, an increase in water requirements (Dai et al., 2009) to warrant demand for evaporative cooling. Thus, lower water availability during such a condition would complicate the burden on water balance. Owed to the close association between feed intake and water consumption, any lessening in water accessibility would be accompanied by a decline in feeding activity (Savory, 1978; Abdelsamie and Yadiailo, 1981). Also, it has been revealed that feed consumption declined with water restriction in broilers together with a concurrent impairment in feed conversion (Kellerrup et al., 1965; Viola et al., 2009). Savory, 1978 reported that restricting water to 90% of the *ad libitum* drinking resulted in a decline in feed intake in laying hens. This decline in feed intake could be viewed as a need to preserve body water by reducing faecal water loss together with reducing body heat increment and consequently, evaporative water loss. Restricting water to 100 g/d markedly reduced egg production and live weight in laying hens (Fujita et al., 2001) and this decline in productive performance is mostly affected by the fall in feed intake (Savory, 1978). There are many stressors that can induce stress response for chickens during various

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phases of production (Siegel, 1995).Those of importance in the later stages of production such as management failure for provision of adequate feed or water (Scheele, 1997). Except for those avian species which are able to survive without drinking water, the minimum water requirements are typically one- third to one- half of the *ad libitum* drinking rate (Skadhauge, 1981). Stress response elicited endocrine and immune changes (Huff et al., 2008) with a strong individual variation linked with genetic control through specific genes (Redei, 2008). Teresa et al. (2009) demonstrated that, water and feed to water ratio of modern broiler genetic strains are higher compared to non-selected broilers. The most noticeable effect of water restriction stress is reduced feed intake and reduce productivity (Esonu, 2000). Laying hens show overeating at late phase of production which is not consistent with their production rate, and this overeating behavior has been reported earlier (Savory, 1978). This study was conducted to determine the acceptable limit of short-term water restriction using two different genetically background birds in the late phase of production, in an attempt to cope with the expected problem of high feed and water consumption at this phase. This have been done considering explaining the effect of this restriction on body weight, egg production, and immune response under hot and arid environmental conditions.

MATERIALS AND METHODS

Bird's husbandry

Ninety layers (fifty weeks-old) were used in this experiment, 45 Hisex commercial layers and 45 local Saudi breed layers. Each breed was wing banded and randomly assigned to groups of five into nine floor pens, three replicates for each treatment, with wood shavings as litter, feeders, drinkers, and laying nests were provided in a conventional experimental open house system. The minimum, maximum and average temperature and relative humidity during the experimental weeks are summarized in Table 1. The average environmental temperature was 37.2-38.6°C, which is considered to be within the average seasonal temperature at this region. Relative humidity was between 20 to 37%. Feed was available *ad libitum*, and the birds were fed a commercial layer diet with 16% protein and ME of 2,700 Kcal/kg feed. They were provided with a photoperiod of 16 h (0500 to 2100 h) light and 8 h dark. Each breed was assigned to three drinking water regimes. The experiment was divided into 3 periods; control (1 week), water restriction (2 weeks) and rehydration (1 week). During the control period, all layers were allowed free water *ad libitum*. Layers from each breed were divided into three groups that received 20, 40 and 0% water restriction. The restriction of water was related to the free water intake during the control period. During the restriction period, layers had access to water from 07:00 h until the allotted quantity of water was consumed. Layers were then allowed free water *ad libitum* during the rehydration period. Each pen contained two suspended feeders and two plastic inverted water drinkers with a capacity of 4 liters, and similar water containers were placed nearby to correct for water evaporation.

Table 1. Average, maximum and minimum temperature and average relative humidity during weeks 0, 1, 2, and 3 of the experiment

Weeks	Temperature (°C)			Relative humidity (%)
	Average	Maximum	Minimum	
0	38.4±0.4	41.7±0.3	34.8±0.6	26.6±2.3
1	37.8±0.2	41.2±0.2	34.1±0.5	34.3±1.3
2	38.6±0.3	41.8±0.1	35.2±0.4	31.4±3.0
3	37.2±0.3	41.2±0.3	33.6±0.4	31.9±2.1

Parameters and data collection

Both feed and water consumption of all groups were measured every week to establish each the mean daily feed and water consumptions for each bird. Then water/feed ratios were calculated. Body weight changes were determined by measuring live weight for each bird to the nearest 10 g on a weekly basis starting from week zero of the experiment. Data of weekly body weight were used to calculate the percent of changing in body weight. Rectal temperature was recorded for couple of birds from each replicate on a daily basis. Egg production was recorded on a daily basis for each replicate, and then the hen day egg production percent was calculated. After one week of water regimes all chickens were intramuscularly injected with Sheep red blood cells (SRBC) as indicator for their humoral immunity. Blood samples were obtained from each bird at 3, 7, and 10 d after immunization. Sera were collected after centrifuging the blood samples and were stored at -20°C until all assays were run simultaneously. The SRBC antibodies were assayed by micro agglutination (Zhou et al., 2001).

Statistical analysis

The data from this study were subjected to a two-way analysis of variance for the effect of breed and treatment and their interactions. Means were separated by use of Duncan's multiple range tests. Data were analyzed using the General Linear Model procedure of SAS software (SAS, 2000). Statistical significance was considered as ($p \leq 0.05$) throughout the paper.

RESULTS

Feed, water and body weight

Table 2 demonstrates the comparative responses of the

Table 2. Feed consumption and water/feed ratio at weeks 0, 1, 2, and 3 of the experiment

Treatment	Average feed consumption (g/bird/d)				Water/feed ratio			
	wk 0	wk 1	wk 2	wk 3	wk 0	wk 1	wk 2	wk 3
T1[1]	107.32±2.4 A	125.2±3.7 A	128.8±16.6 A	104.2±12.0 A	3.61±0.44 A	2.50±0.28 B	2.68±0.58 B	2.95±0.18 B
T2	109.9±3.1 A	132.6±4.6 A	125.5±30.4 A	100.2±14.2 A	3.10±0.43 A	1.50±0.21 C	2.23±0.67 B	2.13±0.34 B
T3	102.8±4.2 A	135.7±6.2 A	107.4±18.3 A	90.5±10.4 A	3.66±0.23 A	3.00±0.12 A	4.20±0.68 A	4.50±0.57 A
Breed								
Local	109.1±2.4 A	136.2±4.0 A	160.5±13.6 A	89.8±11.1 A	2.84±0.25 B	2.02±0.29 B	1.77±0.31 B	3.34±0.63 A
Commercial	104.2±2.9 A	126.2±3.7 A	80.6±9.2 B	106.8±7.5 A	4.06±0.19 A	2.64±0.21 A	4.30±0.45 A	3.04±0.18 A

[a,b,c] Values within a week between breeds or treatments with different superscript differ significantly (p≤0.05).
[1] T1, T2, and T3 are 20%, 40%, and 0% water restriction respectively.

Table 3. Body weight and percent of changing in body weight over the weeks of experiment

Treatment	Body weight (g)				Changing in body weight %		
	wk 0	wk 1	wk 2	wk 3	wk 1	wk 2	wk 3
T1[1]	1,300.0±29.8 A	1,222.6±33.9 A	1,146.6±33.3 B	1,242.1±35.9 A	96.54±0.89 B	91.01±1.11 B	97.94±1.02 AB
T2	1,330.0±29.7 A	1,291.3±31.1 A	1,221.4±30.5 AB	1,302.0±35.3 A	95.37±0.82 B	89.64±1.01 B	96.11±1.00 B
T3	1,323.9±27.6 A	1,308.0±28.7 A	1,305.2±27.7 A	1,308.7±31.5 A	99.71±0.76 A	99.64±0.92 A	99.81±0.89 A
Breed							
Local	1,142.9±23.9 B	1,134.4±25.1 B	1,080.9±24.6 B	1,131.9±28.0 B	98.32±0.67 A	94.34±0.82 A	98.94±0.79 A
Commercial	1,489.5±23.4 A	1,426.1±26.0 A	1,389.7±25.4 A	1,440.3±28.0 A	96.29±0.69 B	93.37±0.84 A	97.14±0.80 A

[a,b,c] Values within a week between breeds or treatments with different superscript differ significantly (p≤0.05).
[1] T1, T2, and T3 are 20%, 40%, and 0% water restriction respectively.

treatment groups in their feed consumption and water/feed ratio. The means of feed intake among treatment groups were comparable indicating that water restriction did not affect feeding activity. Water to feed ratio exhibited a proportional decline with the increase in the magnitude of water restriction particularly during the first week of restriction. There was a breed effect on the rate of water consumed per g of feed intake where the local breed had a lower values compared to the commercial breed but local breed increased their water: feed ratio to the level of the other breed during the second week of water restriction.

Water restriction did not produce any obvious effect on the absolute values of live weight except for a transient decline with 20% restriction during the second week of water restriction (Table 3). Local breed had a significantly ($p<0.05$) lower live weight compared to the commercial breed. However, results of percentage of live weight change indicated a significant decline in the water restricted groups with a trend of recovery in both groups, but with more increase in live weight in the group received 20% water restriction compared to control ones.

Figure 1 illustrates the changes in feed consumption in the two breeds in response to water restriction. There were no significant effects of breed or treatment on feed intake during both pre-treatment and the first week of water restriction. Water restriction did not affect the level of feeding in the local breed while it tended to decline in the 40% group of commercial breed compared to local ones during the second week of restriction period.

There was a tendency of higher water: feed ratio in the commercial group compared to that of the local group (Figure 2). Water: feed ratio generally maintained at a significantly lower values in the water-restricted groups irrespective of breed. Further analysis of the data revealed a consistently lower water feed ratio in the 40% water restricted group compared to the group received 20% restriction in local breed. While it was maintained at a similar levels in the commercial group, irrespective of water restriction rate, except for the first week of restriction where it was significantly lower in the 40% group compared to the 20% group.

As shown in Figure 3 live weight was significantly lower during the second week of water restriction in the local breed while it was lower in the 40% group compared to control ones in the commercial group. Water restriction effects on the fall of live weight commenced at the first week of restriction in the commercial group, with a further decline towards the next week of restriction. On the other hand, changes in the live weight were evident only during the second week of restriction in the local breed. A recovery in live weight was evident during the rehydration period in all groups that had been receiving the water restriction treatment. Live weight changes of the water restricted groups decreased during the first week of restriction in the

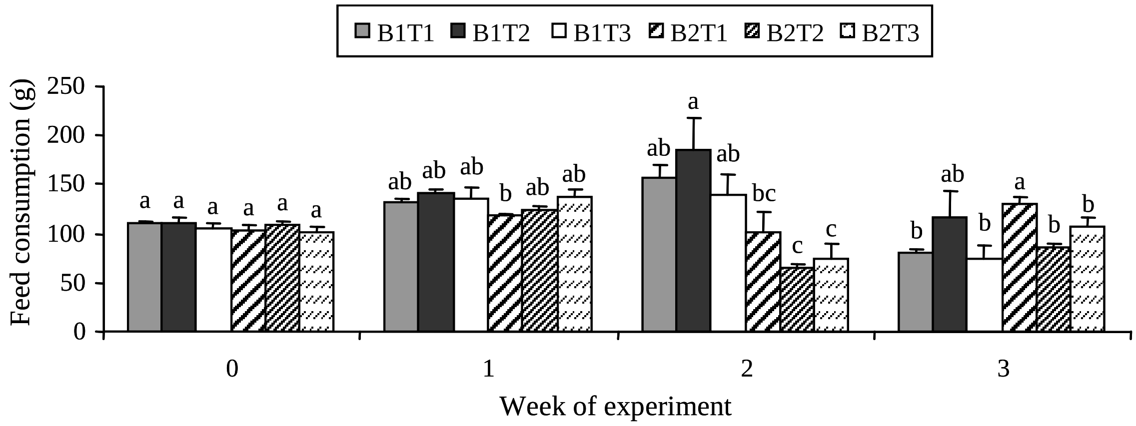

Figure 1. Feed consumption of different breeds (B) and treatments (T) over the experimental period. Columns within a week with different superscript differ significantly (p≤0.05). T1, T2, and T3 are 20%, 40%, and 0% water restriction respectively. B1 and B2 are local and commercial breed respectively.

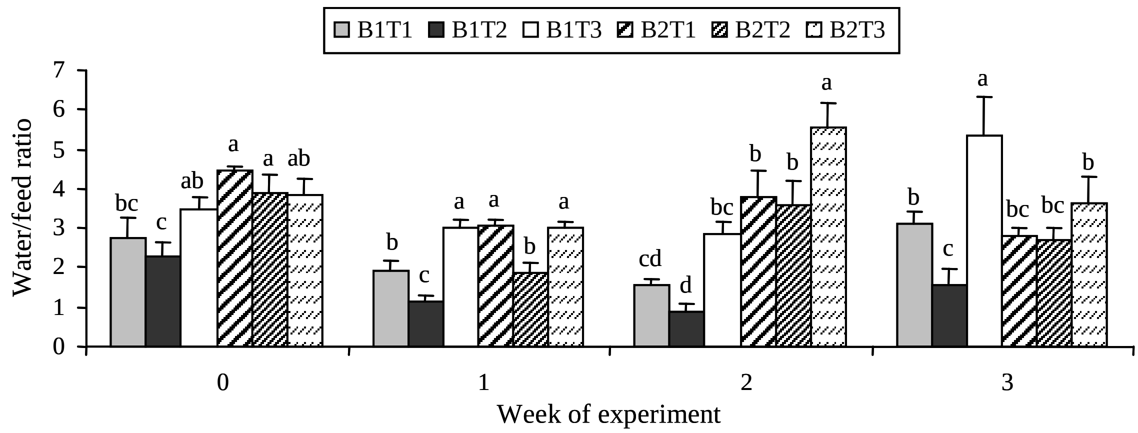

Figure 2. Water:feed ratio of different breeds (B) and treatments (T) over the experimental period. Columns within a week with different superscript differ significantly (p≤0.05). T1, T2, and T3 are 20%, 40%, and 0% water restriction respectively. B1 and B2 are local and commercial breed respectively.

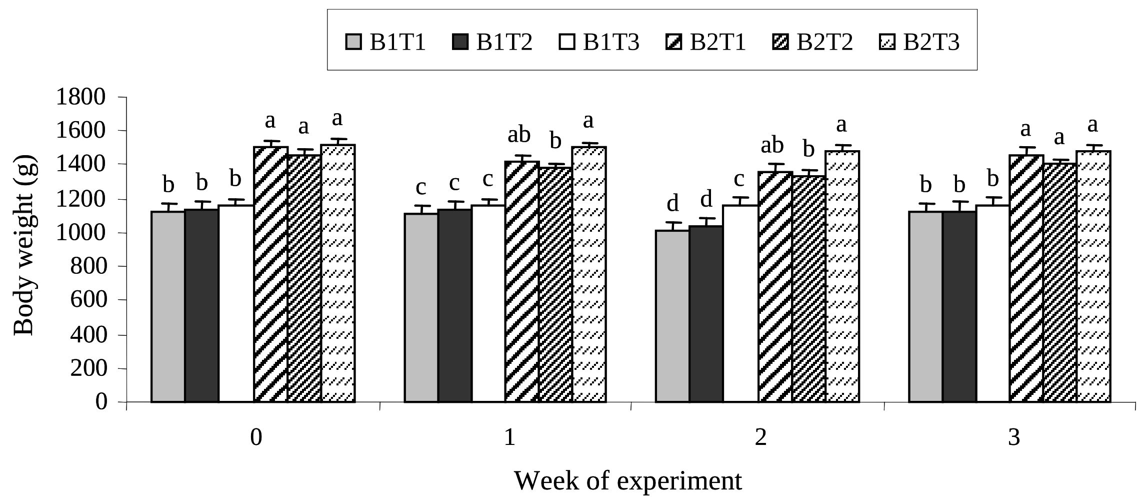

Figure 3. body weight of different breeds (B) and treatments (T) over the experimental period. Columns within a week with different superscript differ significantly (p≤0.05). T1, T2, and T3 are 20%, 40%, and 0% water restriction respectively. B1 and B2 are local and commercial breed respectively.

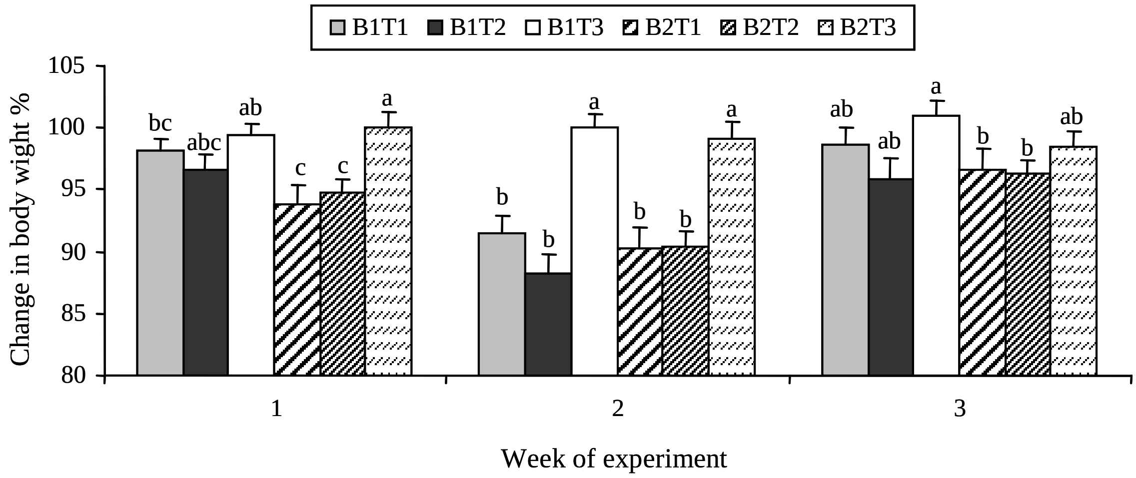

Figure 4. Changing in body weight percent of different breeds (B) and treatments (T) over the experimental period. Columns within a week with different superscript differ significantly (p≤0.05). T1, T2, and T3 are 20%, 40%, and 0% water restriction respectively. B1 and B2 are local and commercial breed respectively.

commercial group irrespective of water restriction rate (Figure 4). However, live weight did not fall until the second week of restriction in the local breed. During the rehydration period, restricted groups increased their live weight to the values of the control groups irrespective of breed.

Egg production and immune response

The percent of egg production and primary antibody response to SRBC are shown in Table 4. Results showed an obvious significant (p≤0.05) decrease in egg production percent with 40% water restriction in comparison with other groups. This trend was evident during restriction period but also extended to the rehydration week. Egg production was significantly the lowest for group received 40% water restriction during the weeks of water restriction in the commercial breed (Figure 5). However, there were no differences in egg production in the local breed between birds at different restriction levels. Local group received 40% water restriction recorded a significant (p≤0.05) reduction in egg production compared to control group starting from the second week of water restriction. No significant differences in egg production could be detected between group received 20% water restriction and control group throughout the experimental period for both local and commercial breed (Figure 5).

Water restriction treatment affected the immune response to SRBC at 7 days post exposure (Table 4). Groups received 20%, and 40% water restriction showed significantly lowest antibody titer to SRBC at 7 d post exposure compared to control group. No differences in antibody titer were observed in any other measuring point. Commercial breed was significantly (p≤0.05) slow responder compared to local group at 3 d post exposure while, they recorded significantly (p≤0.05) higher titer than local breed at 10 d post exposure (Table 4). Water restriction did not affect antibody titer to SRBC for the commercial breed at any measuring point post injection, while, it was affected in local breed (Figure 6). In the local breed, both water restriction regimens induced lower titer compared to control group following 7 days of exposure. Furthermore, the local breed group that received 20% restriction showed significantly (p≤0.05) lower antibody titer than control group throughout measuring times.

Table 4. Egg production percent (EP), and Primary antibody response to SRBC

Treatment	Egg production (%)			Antibody titer to SRBC		
	wk 1	wk 2	wk 3	3 d[2]	7 d	10 d
T1[1]	36.33±2.56 [A]	41.50±3.58 [A]	41.66±4.88 [A]	1.50±0.27 [A]	3.21±0.34 [B]	3.38±0.34 [A]
T2	22.34±4.82 [B]	20.00±5.25 [B]	24.66±5.27 [B]	1.30±0.26 [A]	3.45±0.35 [B]	4.09±0.30 [A]
T3	38.50±2.01 [A]	45.50±4.24 [A]	41.50±3.91 [A]	1.92±0.23 [A]	4.20±0.29 [A]	4.16±0.27[A]
Breed						
local	31.33±2.57 [A]	36.00±5.75 [A]	30.33±4.39 [B]	2.32±0.20 [A]	3.84±0.27 [A]	3.47±0.24 [B]
Commercial	33.44±4.47 [A]	35.33±4.75[A]	41.55±4.07 [A]	0.85±0.21 [B]	3.50±0.26 [A]	4.41±0.26 [A]

[a,b,c] Values within a measuring time between breeds or treatments with different superscript differ significantly (p≤0.05).

[1] T1, T2, and T3 are 20%, 40%, and 0% water restriction respectively. [2] 3 d, 7 d, and 10 d are days 3, 7, and 10 post injection.

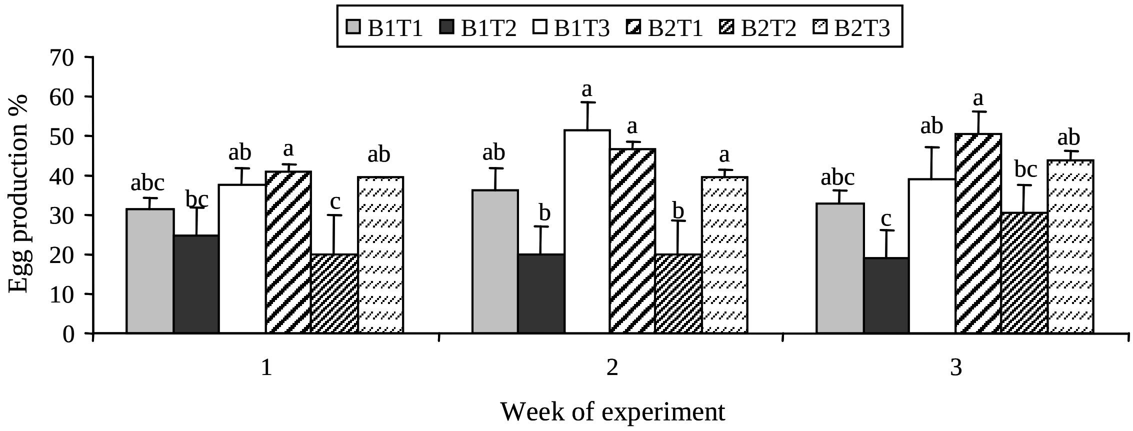

Figure 5. Egg production % of different breeds (B) and treatments (T) over the experimental period. Columns within a week with different superscript differ significantly (p≤0.05). T1, T2, and T3 are 20%, 40%, and 0% water restriction respectively. B1 and B2 are local and commercial breed respectively.

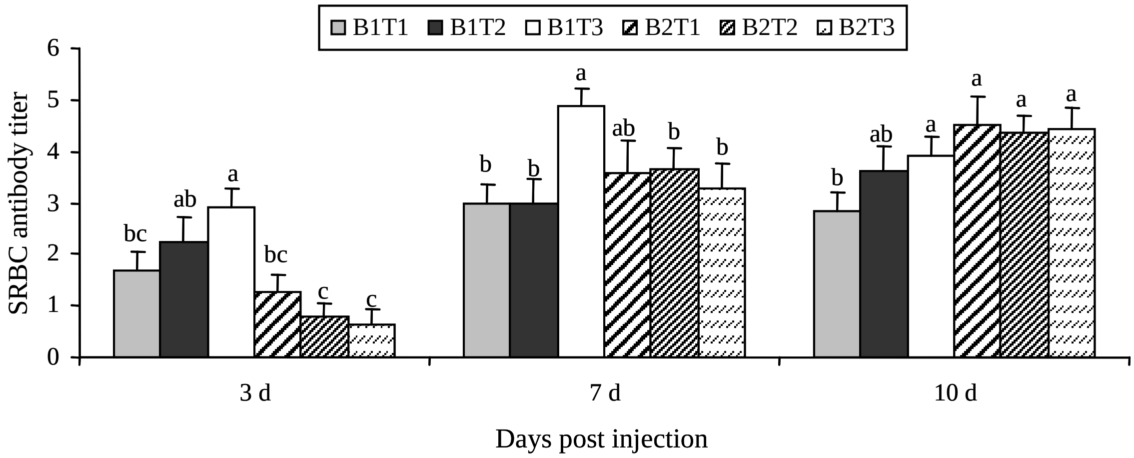

Figure 6. Antibody titer against Sheep red blood cells (SRBC) antigen of different breeds (B) and treatments (T) over the experimental period. Columns within a week with different superscript differ significantly (p≤0.05). T1, T2, and T3 are 20%, 40%, and 0% water restriction respectively. B1 and B2 are local and commercial breed respectively.

Water restriction did not produce any effects on rectal temperature in the local breed while it decreased significantly in the commercial groups during the second week of water restriction (Figure 7). Also, it was remained below control values in the 40% restricted group of the commercial layers during rehydration.

DISCUSSION

Water restriction in the present study did not result in any obvious effect on feed intake in the local breed. However, commercial layers responded differently when they reduced their feed intake with 40% water restriction compared to local breed. Earlier study by Savory (1978) has also reported a fall in feed intake in layers hens with only 10% water restriction when maintained under thermoneutral conditions. It is well recognized that during periods of water insufficiency animals may reduce their feed intake which is considered to be one major avenue of water saving mechanisms. However, the degree of water stress severity and the adaptation to water shortage will determine the rate of fall in feed intake. Therefore, it is possible to postulate that the observed fall in feed intake in the commercial group with 40% restriction indicating that water restriction was more severe compared to the local group with the same level of water restriction. On the other hand, maintaining feed intake during periods of water deficiency could be regarded as an important adaptive mechanism employed by animals inhabiting hot and arid regions, thus their performance is least impaired during water shortage conditions. The local group is well-adapted to the prevailed environmental conditions such as higher ambient temperature and water scarcity, and therefore, they inherited a tolerable feature of water deficiency. The observed fall in feed intake during the second week of restriction in the commercial group cannot be accounted for water restriction

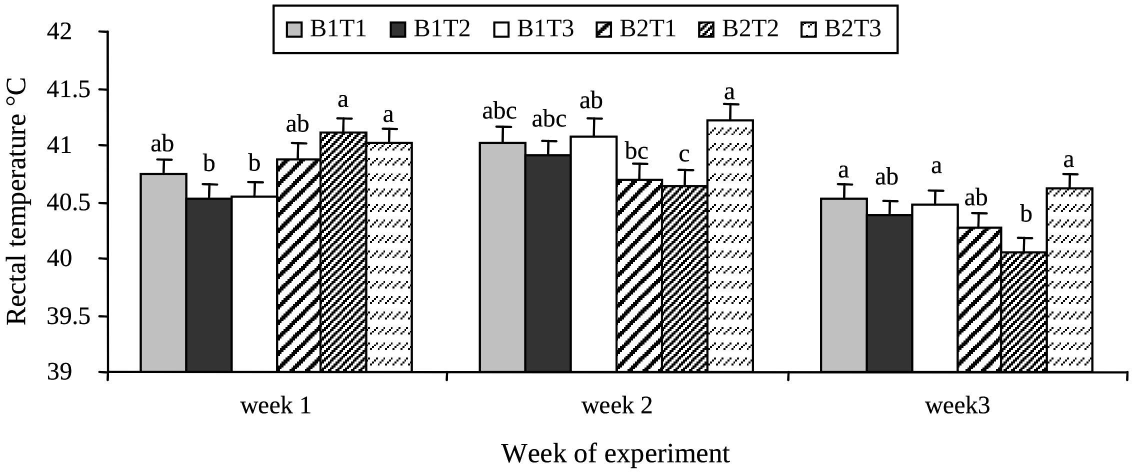

Figure 7. Rectal temperature during the experimental time for different treatments. Columns within a week with different superscript differ significantly (p≤0.05). T1, T2, and T3 are 20%, 40%, and 0% water restriction respectively. B1 and B2 are local and commercial breed respectively.

since a general trend of feed intake reduction was evident in all groups of these layers. This fall in feed intake may be explained by a possible interaction between ambient temperature and feed intake since the recorded temperature tended to be higher during the second week of restriction compared to the previous week.

When the overall means of the consumed water is compared on a per g feed intake basis, the local breed consumed less water than the other group. Accordingly, it is feasible to suggest that the lower water intake in the local breed could be a reflection of their lower water requirements and capability of budgeting body water more economically than the commercial layers. The water turnover rate is related to the metabolic rate and the distinct variation of water requirements between the two breeds can be explained in evolutionary terms through the different adaptation strategies of the two breeds. Local breed is evolved in a very hot and dry region and therefore, it is well adapted to such harsh conditions. It is possible that this breed has an energy conserving lifestyle, which enabled them to minimize water needs for metabolism and nitrogen excretion. On the other hand, commercial group has been selected on higher quality ration and therefore, needs a higher water turnover rate for the excretion of nitrogen in the excreta.

Live weight declined with water restriction almost at a similar rate in the two restriction regimens during the first week of restriction but with a further fall in the second week of water insufficiency. Abdelsamie and Yadiwilo (1981) reported a drop of 18% in body weight in broilers maintained on a 25% water restriction under hot arid conditions. Despite the distinct variation in the degree of water deficiency between the two water restriction levels, no obvious differences were found between the two groups in their live weight changes to water restriction. Body weight loss during negative water balance situations can be ascribed to mainly to body water losses together with the fall in feed and water intakes. It could be postulated that due to sever water deficient, the 40% group evoked a more body water saving mechanism which might attenuated body water losses. This would result in comparable body weight losses between the two water restriction regimens. However, there was a possible breed differences in body weight loss; a significant reduction in live weight was delayed until the second week of restriction in the local breed while a clear decline in body weight was obvious in the commercial group irrespective of level of restriction. Similarly, Arad (1982) reported a significantly higher rate of live weight loss in commercial Leghorn breed compared to native ones during water deprivation under hot conditions. This could be related to a possible variation in water expenditure and utilization between the two breeds since the local breed exhibited a lower water intake which indicating lower water requirements and utilization. Therefore, they were able to budget their water balance by various means of reduction of water usage and expenditure. However, the commercial breed was more water dependence and therefore with larger weight loss compared to local breeds. In addition, the delay of live weight loss in the local breed could be attributed to the observed rise in feed intake during the second week of water restriction, which might have increased body water expenditure associated with feed intake increment.

It is recognized that water restricted birds reduce their thermoregulatory evaporation and allow their body temperature to be elevated in order to save body water (Arad, 1983; Arad and Skadhauge, 1984). In the present study, however, birds were able to adjust their thermoregulatory mechanism and hence homeothermy was maintained despite the strain on body fluids. The observed decline in rectal temperature in the water-restricted group of the commercial breed can be related to a general reduction in metabolic rate in an effort to reduce heat increment and avoid the occurrence of hyperthermia.

The current research results indicated that 40% water restrictions negatively affected egg production irrespective of breed. However, this response was evident during the first week of restriction in commercial line but it was delayed until the second week of restriction in the local breed. Water restriction up to 20% under the current experimental conditions has been shown as a safe limit of restriction concerning egg production for local and commercial lines. Early research work (Savory, 1978) reported no difference in egg production in 10% water restricted Brown Leghorn and control group for 6 weeks. On the other hand (Fujita et al., 2001) reported that egg production rate was not affected by 40% or 60% water restriction in Shaver Starcross layers, while the threshold of negative effects on egg production was 80% water restriction. It is worth noting that the previous studies were using thermo neutral environmental conditions, compared to the current experimental conditions. Moreover the genetic pool of the local breed is well adapted to the harsh environmental conditions which enable them to tolerate water restriction 1 week later than commercial line. During water stress under the current environmental conditions and at the threshold of effect, it is suggested that the hypothalamic osmoreceptors are activated by the increase of blood tonicity and the hypothalamic- hypophyseal-adrenal axis is consequently activated as well. This would results in an increased arginine vasotocin (AVT), prolactin and probably ACTH. These hormones increase water re-absorption to cope with water restriction stress, while decline egg production rate.

The results of antibody production against SRBC antigen indicated an obvious decline in antibody titer after 14 days of restriction compared to control group. Further analysis of the data indicated that the local breed has been shown to be the highly affected compared to the other breed. The decline of immune response to SRBC in hens has been reported previously under ACTH treatment (Puvadolpirod and Thaxton, 2000; Odihambo et al., 2006). When, plasma corticosterone levels of laying hens increase during exposure to stressors (Beuving et al., 1989) and water restriction stress is considered to be a stressor. Lymphocytes have receptors for corticosterone in the cytoplasm, and these receptors have been shown to increase during immune stimulation (Freier and Fuchs, 1994). Free steroids can pass cell membrane and bind these receptors and consequently steroid-receptor complex suppress the cell protein synthesis (Lewis and Jacobs, 2002). Local breed are highly diverse in genetic pool than commercial line, and they are well adapted to hot and arid environment, so we suggested that the hypothalamic osmoreceptors activation is under different genetic- environment control in both breeds which show the difference in response to SRBC following 2 weeks of water restriction.

In conclusion, water restriction did not result in any obvious effect on feed intake in the local breed. Body weight and egg production were not affected by water restriction following 1st week of treatment in the local breed while commercial line responded differently. The SRBC immune response was reduced in the local breed during water restriction but it was remained unchanged in the commercial group. Twenty percent of water restriction is considered to be a safe limit of water restriction under the current experimental conditions, without negative effect on egg production in both breeds with considering the immune status and body weight of the local breed starting from the second week of restriction. Forty percent of water restriction has induced a negative effect on egg production, and varied effects on the other traits in both breeds.

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