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THE USE OF EARLY-AGE FEED RESTRICTION AND/OR POTASSIUM CHLORIDE FOR ALLEVIATING THE ADVERSE EFFECTS OF HEAT STRESS ON BROILER CHICKS:
1. EFFECTS ON BROILER PERFORMANCE, CARCASS TRAITS AND ECONOMIC EFFICIENCY.

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ABSTRACT

The present study was carried out to investigate the possibility of alleviating the adverse effects of heat stress to which broiler chicks are exposed during the summer season by means of early-age feed restriction (EFR) and/or dietary supplementation with potassium chloride (KCl). Three hundred and sixty, one-day-old, broiler-type Hubbard chicks were randomly divided into two halves, each of which was assigned to four treatments (T), and given starter diets from 1 to 21 days of age, then, the birds were switched to grower diets from 22 to 42 days of age. Two feeding regimens were imposed on these birds. Chicks of the first half (T1, T2, T3 and T4) were full-fed (FF) during the entire experimental period from 0 to 6 weeks of age, while birds of the other half (T5, T6, T7 and T8) were subjected to feed restriction; only during the first week of life. Each of the starter and grower diets were isocaloric and isonitrogenous, and originally contained about 0.8% K. Diets of T1 and T5 were unsupplemented with KCl and served as controls, while diets for chicks of T2 and T6, T3 and T7 or T4 and T8, were supplemented with KCl at levels of 0.75, 1.5,and 2.25%, respectively. Thus, in these diets, supplemental KCl plus basal K provided dietary K levels of 0.8, 1.2, 1.6 or 2.0%, respectively.

The criteria of response were live body weight, weight gain, feed intake, feed conversion ratio, mortality rate, carcass traits, and economic efficiency. The obtained results can be summarized as follows: Early feed restriction (during the first week) had no significant effects on final body weight (at 6 weeks of age), weight gain, mortality rate of chicks or their carcass traits, but significantly decreased feed intake and improved the efficiency of feed utilization. Dietary KCl levels of 1.5 or 2.25% resulted in significant increases in live body weight, improved the efficiency of feed utilization of chicks and attained the lowest mortality rate, while carcass traits were not affected. The use of early-age feed restriction, and/or supplemental KCl especially at a level of 1.5 or 2.25% reduced mortality rate, and improved weight gain and feed conversion of chicks. But because the combination of early-age feed restriction and dietary inclusion of KCl at a rate of 2.25% significantly improved the viability of chicks as evidenced by no observed mortality, it had the advantages over the other treatments; for the sake of safety and economic use under hot environmental conditions of summer season, as is the case of the present study.

Keywords: broiler performance, early-age feed restriction, dietary potassium chloride.

INTRODUCTION

High ambient temperature is one of the most important stressors to which poultry are exposed. It impacts on the profitability of chicken meat and egg production enterprises in many regions of the world. Adverse effects of heat stress include increased mortality, reduced appetite and poor deleterious effects of high environmental temperature on broiler chicks performance have been documented (Cahaner and Leenstra, 1992; Eberhart and Washburn, 1993; and Yalcin *et al,* 1997).

Several reports in the literature indicated that the adverse effect of high temperature on broiler chicks performance included weight gain and feed intake reduction (Teeter *et al*, 1985) and increase in mortality (Reece *et al*, 1972). The growth rate of 4 to 8-week old broiler chicks was maximal at environmental temperature of 18 to 20°C, while maximal feed efficiency was obtained at 24°C (Hurwitz *et al*, 1980), and a progressive decline in their weight gain and feed intake was obtained as ambient temperature increased from 18 to 35°C (Yahav *et al*, 1995, 1996). At temperatures exceeding 38°C, thermotolerance is overcome, leading to marked mortality (Squibb and Wogan, 1960).

The adverse effect of high ambient temperature on the performance of poultry is usually ameliorated by manipulation of housing conditions, nutrition (Cerniglia *et al*, 1983; Lacy and Czarick, 1992; and Balnave and Gorman, 1993), and genetic improvement for heat tolerance (Cahaner *et al*, 1993). In developing countries, nutrition and genetic factors are more likely to be used to combat heat stress because cooling the poultry house is expensive (Cahaner, 1990). Therefore, some management techniques and dietary manipulations; beside evaporative cooling and insulation, have been commonly investigated to cope with the effect of high ambient temperature on the performance of broiler chicks.

Several reports confirmed the benefits of a short period of severe feed restriction early in life on feed efficiency and fat deposition in broiler chicks, while obtaining comparable body weights at market age. When the feed of chicks was restricted to an energy intake calculated to provide maintenance requirements for 6 to 7 days during the first two weeks of age, they have consistently showed a reduction in abdominal fat, reduced mortality rate, improved feed efficiency and a similar body weight to full-fed birds up to 56 days of age (Plavnik *et al*, 1986; Plavnik and Hurwitz, 1989; McMurtry *et al* 1988a,b; Calvert *et al*, 1989; Fontana *et al*, 1992; and Zhong *et al*, 1995).

Some reports indicated that feed withdrawal or restriction prior to the onset of acute heat stress reduced the mortality of broiler chicks and increased their survival (Smith and Teeter, 1988; and Smith, 1990). It was unknown, however, whether an early-age feed restriction can carry over its well established beneficial effects that may increase the ability of broiler chicks to withstand exposure to high environmental temperature later in life, similar to that observed with early-age thermal conditioning (Yahav and Plavnik, 1999; and Zulkifli *et al*, 2000).

Other reports demonstrated that dietary supplementation with some electrolytes (i.e. NH_4Cl, Na_2CO_3, $NaHCO_3$, KCl, K_2CO_3 and NaCl) may enable the birds to cope partially or more completely with chronic or acute heat stress, as evidenced by reduced mortality, improved weight gain and feed efficiency, increased water consumption and correction of blood acid-base balance (Teeter *et al*., 1985; Smith and Teeter, 1987a,b,c; Smith and Teeter, 1989; and Deyhim and Teeter, 1991).

Therefore, the aim of the present study was to investigate the possibility of alleviating the adverse effects of heat stress to which broiler chicks are exposed during the summer season, by means of early-age feed restriction and/or dietary supplementation with potassium chloride. Criteria of response included performance of chicks for weight gain and feed conversion, viability of chicks, carcass traits and economic efficiency.

MATERIALS AND METHODS

The present study was conducted (from June to August 2000) at the Poultry Farm; Agricultural Researches and Experiments Station; Faculty of Agriculture, Mansoura University.

Experimental birds and diets:

Three hundred and sixty, one-day-old, unsexed broiler-type Hubbard chicks, having an average body weight of 47.5g, were wing-banded and randomly divided into two halves, each of which was assigned to four treatments (T) of three replicates containing 15 chicks each. The chicks were raised during the brooding and growing periods in batteries with wire-floor decks, placed in a naturally ventilated rearing room, provided with a continuous florescent illumination. During the first two weeks of the brooding period, however, a supplemental heat was provided to chicks. The chicks were vaccinated against New-Castle and Gumboro diseases, reared under similar environmental conditions, and given the experimental starter diets from 0 to 3 weeks of age (1-21days old) and grower diets from 3 to 6 weeks of age (22 - 42 days old).

The experimental diets were formulated to be isonitrogenous and isocaloric; where starter diets contained about 21.6% CP and ME of 3000 Kcal/kg, and grower diets contained 19.6% CP with ME content of 2955 Kcal/kg (Table 1). Two feeding regimens were imposed on the experimental birds. Chicks of the first half (chicks of T1, T2, T3 and T4) were full-fed (FF); on *ad libitum* basis, throughout the entire experimental period (0 to 6 weeks of age), while feed of the other half (chicks of T5, T6, T7 and T8) was restricted; only during the first week, to meet their daily maintenance requirements for nutrients with a concomitant achievement of some growth; as calculated according to (Plavnik and Hurwitz, 1989) equation: 1.5 kcal X $BW^{0.66}$; where BW is the body weight in grams. These early-age feed restricted (EFR) chicks had a free access to feed after the first week and up to the end of the experimental period. This feed restriction amounted to 40% of the normal *ad libitum* feeding. All chicks, however, had a free access to drinking water. Both starter and grower diets had originally about 0.8% potassium. From 1 to 6 weeks of age (8-42 days old), diets of chicks on both the two regimens (FF and EFR) were either unsupplemented with KCl for those in T1 and T5 which served as controls, or supplemented with KCl at levels of 0.75, 1.5, and 2.25 of diets for chicks of T2 and T6, T3 and T7, or T4 and T8, respectively. Thus, in these diets, supplemental KCl plus basal K provided average dietary K levels of 0.8, 1.2, 1.6 or 2.0%, respectively.

Table 1: Chemical composition of the experimental diets.

Ingredients %	Starter diets				Grower diets			
	Supplemental KCl levels				Supplemental KCl levels			
	0	0.75	1.50	2.25	0	0.75	1.50	2.25
Yellow corn	59.70	59.95	58.40	56.65	60.80	61.75	61.40	61.15
Soybean meal (44%)	27.10	27.10	27.30	27.70	25.40	25.50	25.70	25.70
Wheat bran	3.80	2.60	2.50	2.50	7.60	5.70	4.90	4.00
Fish meal (70%)	5.50	5.70	5.80	5.80	2.80	3.00	3.10	3.30
Limestone (38% Ca)	0.88	0.88	0.88	0.88	0.90	0.90	0.90	0.90
Bone meal (29.8% Ca)	1.62	1.62	1.62	1.62	1.50	1.50	1.50	1.50
Sunflower oil	0.50	0.50	1.10	1.70	0.30	0.20	0.30	0.50
Common salt	0.40	0.40	0.40	0.40	0.30	0.30	0.30	0.30
Vit. & Min. Premix*	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
DL-methionine	0.20	0.20	0.20	0.20	0.10	0.10	0.10	0.10
KCl	0.00	0.75	1.50	2.25	0.00	0.75	1.50	2.25
Total	100	100	100	100	100	100	100	100
Calculated analysis (air dry basis):								
ME; kcal/kg	3001	3000	3002	3001	2954	2960	2953	2955
Crude protein %	21.56	21.55	21.56	21.58	19.55	19.55	19.57	19.56
C/P ratio	139	139	139	139	151	151	151	151
Ether extract %	3.67	3.54	4.19	4.73	3.32	3.22	3.30	3.48
Crude fiber %	3.65	3.64	3.51	3.50	3.97	3.79	3.71	3.61
Ca %	1.04	1.04	1.04	1.04	0.95	0.95	0.95	0.95
Total P %	0.68	0.67	0.67	0.67	0.66	0.64	0.64	0.63
K	0.83	1.20	1.58	1.96	0.82	1.18	1.55	1.92
Lysine %	1.21	1.22	1.22	1.22	1.04	1.05	1.05	1.06
Methionine %	0.60	0.61	0.61	0.60	0.44	0.45	0.45	0.45
Meth. + Cyst. %	0.94	0.94	0.94	0.94	0.77	0.77	0.77	0.77
Determined analysis:								
Moisture %	8.56	8.69	8.41	8.37	8.50	8.77	8.77	8.65
Dry matter %	91.44	91.31	91.59	91.63	91.50	91.23	91.23	91.35
Crude protein %**	23.89	23.91	23.88	23.92	21.52	21.54	21.55	21.54
Ether extract %**	3.93	3.86	4.59	4.96	3.67	3.61	3.65	3.89
Crude fiber %**	4.22	4.16	3.98	4.01	4.55	4.43	4.32	4.21
Ash %**	6.36	6.67	6.89	7.33	6.47	6.59	6.96	7.35
NFE %**	61.60	61.40	60.66	59.78	63.79	63.83	63.52	63.01
K %**	---	---	---	---	0.91	1.34	1.71	2.07
Cost of 1 kg feed; L.E.***	0.865	0.925	0.994	1.06	0.745	0.804	0.864	0.927

*: Each 3 Kg premix contain: Vit. A 12000000 I.U.; Vit. D_3 2500000 I.U.; Vit. E 10g; Vit. K 2.5g; Vit. B_2 5g; Vit. B_6 1.5g; Vit. B_{12} 10 mg; Biotin 50 mg; Folic acid 1g; Nicotinic acid 30 mg; Pantothenic acid 10 g; Antioxidant 10g; Mn 60g; Cu 10g; Zn 55g; Fe 35g; I 1g; Co 250 mg; Se 150 mg.

**: Determined on dry matter basis.

***: Calculated according to the prevailing market prices of feed ingredients during the experimental period, including the price of supplemental KCl.

Measurements:

Criteria of response included data on the performance of chicks for weight gain and feed conversion ratio, mortality rate, carcass traits, and economic efficiency. To measure the body weight (BW) and weight gain (BWG), chicks were individually weighed, while their feed intake (FI) and feed conversion ratio (FCR) were recorded weekly on a replicate basis throughout the whole experimental period. But mortality was daily recorded and its cumulative rate was calculated. At the end of the feeding trial at 6 weeks of age, 5 chicks from each treatment; whose body weights were near the average of their respective treatment, were selected for slaughter test.

Daily ambient temperature and relative humidity fluctuations were recorded during the experimental period. Furthermore, records of prevailing temperature and relative humidity in Dakahliyah Governorate during the experimental period were quoted from the annual reports of Egyptian weather-Forecast Administration (2000). These records showed that during the growing period from 3 to 6 weeks of age, the experimental chicks were naturally subjected to means of minimum and maximum daily temperatures of 24°C and 33.43°C, respectively. While the relative humidity ranged from 60 to 80% inside the rearing room. Thus, the chicks might suffer from such naturally occurring summer heat stress.

Statistical analysis:

For data processing, QUATTRO PRO software program (Borland International, Inc, 1990) was applied. Statistical analyses were performed, using a multi-factor analysis of variance by the STATGRAPHIC software program (Rockville, 1991). The differences were considered significant at $P \leq 0.05$ or at $P \leq 0.01$.

RESULTS AND DISCUSSION

Performance of chicks:

Data on the effects of feeding regimen and dietary KCl level, and their interaction on live body weight, weight gain, feed intake, and feed conversion and mortality rate of experimental chicks at different ages are presented in Tables 2, 3, 4, and 5, respectively.

Live body weight:

Data in Table 2 show that, early-age feed restriction reduced body weights of chicks significantly ($P \leq 0.01$) at 1,2 and 3 weeks of age compared with those of full-fed chicks. By the 4^{th} week to the end of the feeding trial at 6 weeks of age, however, these significant differences disappeared. Yet, EFR-chicks had insignificantly heavier final body weight of 1919g at the end of the experiment compared with that of FF-chicks (1885g). Irrespective of feeding regimen, at the end of experiment (6 weeks of age), the control group also attained significantly ($P \leq 0.01$) the lightest body weight (1804g) followed by that fed 0.75% KCl-supplemented diet (1878g), with significant difference, and both were significantly inferior to those of the other groups. At this age, groups of chicks fed diet containing either 1.5 or 2.25% KCl had body weights of 1957 and 1967g, respectively, with no significant difference. Analysis of variance revealed that there were significant differences in body weight of chicks, only at 2 ($P \leq 0.05$) and 3 ($P \leq 0.01$) weeks of age, due to the interaction of feeding regimen by KCl level.

Table 2: Means and standard errors for live body weight (g) of the experimental chicks.

Treatments	Live body weight; g[1]					
	Chick's age in weeks					
	1	2	3	4	5	6
Main factors:						
Feeding regimen A						
1 Full feeding	169.4[a]	401.1[a]	753.4[a]	1189	1535	1885
2 Early-age feed restriction	120.6[b]	367.4[b]	726.1[b]	1169	1525	1919
SE	0.93	2.66	5.02	8.69	12.1	15.3
Significance level[2]	**	**	**	NS	NS	NS
KCl level % B						
1 0.00	--	373.2[b]	714.8[b]	1137[b]	1482[b]	1804[c]
2 0.75	--	391.9[a]	752.4[a]	1199[a]	1531[a]	1878[b]
3 1.50	--	382.5[ab]	742.4[a]	1183[a]	1546[a]	1957[a]
4 2.25	--	389.2[a]	749.5[a]	1195[a]	1561[a]	1967[a]
SE	--	3.76	7.10	12.3	17.1	21.5
Significance level[2]	--	**	**	**	**	**
Interaction AB						
T No.						
T1 1×1	--	380.0	706.2	1124	1485	1769
T2 1×2	--	411.3	777.7	1126	1515	1835
T3 1×3	--	399.8	764.1	1197	1569	1953
T4 1×4	--	412.9	765.6	1208	1570	1981
T5 2×1	--	366.4	723.4	1149	1478	1840
T6 2×2	--	372.5	727.2	1173	1548	1921
T7 2×3	--	365.1	720.6	1169	1524	1961
T8 2×4	--	365.5	733.4	1182	1551	1954
SE	--	5.33	10.04	17.40	24.30	31.20
Significance level[2]	--	*	**	NS	NS	NS
Overall mean	--	384.2	739.7	1179	1530	1902
SE	--	1.88	3.55	6.20	8.60	10.90

a-c: Means in the same column having different superscripts are significantly different at P ≤0.05.

1: Average live body weights of one-day-old chick were 47.55 and 47.50 g for FF and EFR groups, respectively.

2: NS= not significant; *= Significant at P ≤0.05; **= Significant at P ≤0.01

Body weight gain:

Data in Table 3 show that, during the period of feed restriction from 0 to 1 week of age, EFR-chicks exhibited a significantly (P ≤0.01) lower average body weight gain (73.2g) compared with that of FF-chicks (121.9g). Upon refeeding of EFR-chicks at *ad libitum* level, this significant difference was disappeared between 1 and 2, 2 and 3, 3 and 4, or 4 and 5 weeks of age; indicating that EFR-chicks compensated for growth and put on similar body weight gain to that of their FF-counterparts. During the period from 5 to 6 weeks of age, EFR-chicks acquired a body weight gain of 393.7g/bird, which significantly (P ≤0.01) surpassed that of FF-chicks (350.2g/bird). During the entire experimental period from 0 to 6 weeks of age, however, both EFR- and FF-chicks exhibited similar body weight gain values of 1871g and 1840g/bird, respectively, with no significant difference.

Table 3: Means and standard errors for body weight gain (g) of experimental chicks.

Treatments	Body weight gain; g						
	Chick's age in weeks						
	0-1	1-2	2-3	3-4	4-5	5-6	0-6
Main factors:							
Feeding regimen A							
1 Full feeding	121.9[a]	231.6	352.4	435.1	348.4	350.2[b]	1840
2 Early-age feed restriction	73.2[b]	246.7	358.7	442.4	355.9	393.7[a]	1871
SE	0.92	5.6	5.8	6.2	7.3	8.7	15.4
Significance level[1]	**	NS	NS	NS	NS	**	NS
KCl level % B							
1 0.00	--	231.1	341.6	421.6	344.3	323.4[b]	1757[c]
2 0.75	--	247.7	360.5	447.2	331.9	347.5[b]	1832[b]
3 1.50	--	236.6	359.9	440.6	364.9	410.5[a]	1911[a]
4 2.25	--	241.2	360.3	445.5	367.3	406.5[a]	1921[a]
SE	--	7.9	8.1	8.8	10.4	12.3	21.8
Significance level[1]	--	NS	NS	NS	NS	**	**
Interaction AB							
T No.							
T1 1×1	--	218.1	326.2	417.2	359.6	285.0	1721
T2 1×2	--	242.5	366.4	448.3	290.1	321.8	1790
T3 1×3	--	227.5	364.3	432.4	378.1	384.0	1911
T4 1×4	--	238.2	352.7	442.3	365.7	410.1	1936
T5 2×1	--	244.2	357.0	425.9	329.1	361.8	1793
T6 2×2	--	252.9	354.7	446.1	373.9	373.1	1873
T7 2×3	--	245.7	355.5	448.7	351.8	437.1	1911
T8 2×4	--	244.1	367.8	448.8	368.8	402.8	1906
SE	--	11.2	11.5	12.4	14.7	17.4	30.8
Significance level[1]	--	NS	NS	NS	**	NS	NS
Overall mean	--	239.1	355.5	438.7	352.1	371.9	1855
SE	--	3.9	4.1	4.4	5.2	6.2	10.9

a-c: Means in the same column having different superscripts are significantly different at P ≤0.05. **1: NS= not significant; **= Significant at P ≤0.01.**

Regardless of feeding regimen, no significant differences were detected in body weight gain among groups of chicks up to the end of the 5th week of age, due to the effect of dietary KCl level. While the differences between 5 and 6 weeks of age, was significant (P ≤0.01). Chicks fed diets containing either 1.5 or 2.25% KCl attained significantly (P ≤0.01) similar body weight gain values. Chicks fed diets containing either 0.0 or 0.75% KCl, exhibited significantly (P ≤0.01) less body weight gains, with no significant difference between them. During the whole experimental period; from 0 to 6 weeks of age, however, significant (P ≤0.01) differences were detected also in chicks body weight gain due to the effect of dietary KCl level. Chicks fed on 0.0% KCl-diet attained significantly the least amount of weight gain, followed by that of chicks fed 0.75% KCl-supplemented diet, with significant difference. Chicks fed on diets containing either 1.5 or 2.25% KCl put on significantly more weight gains of 1911 and 1921g/bird, respectively, with no significant difference. There were no significant differences in chick body weight gain due to the effect of interaction of feeding regimen by dietary KCl level during all age intervals; except of that found during 4 to 5 weeks of age which was significant (P ≤0.01). This lack of interaction between feeding regimen and dietary KCl level, would indicate that each of the two factors had a separate effect on chicks body weight gain.

Feed intake of chicks:

Data in Table 4 show that, during the first week, FF-chicks ate 132.8g/bird, while due to feed restriction EFR-chicks consumed a significantly less amount of feed (53.02g/bird). This significant ($P \leq 0.01$) difference in feed intake remained during the refeeding period within the 2nd week of age; where FF-chicks consumed more feed (395.3g/bird) compared with EFR-chicks (389.1g/bird) during the 2nd week of age. Thereafter, from the end of the 2nd week of age to the end of the feeding trial at 6 weeks of age, no significant differences were observed in weekly feed intake. During the entire experimental period from 0 to 6 weeks of age, however, FF-chicks consumed a significantly ($P \leq 0.05$) greater amount of feed than the EFR-chicks. It is apparent that, during the refeeding period between 1 and 6 weeks of age, even though EFR-chicks compensated well for feed consumption, yet they ate significantly less amount of feed compared with their FF-counterparts.

Table 4: Means and standard errors for feed intake (g) of experimental chicks.

Treatments	Feed intake (FI) / week / g						Total FI
	Chick's age in weeks						
	0-1	1-2	2-3	3-4	4-5	5-6	0-6
Main factors:							
Feeding regimen A							
1 Full feeding	132.8^{a}	395.3^{a}	623.8	831.9	850.3	942.9	3777^{a}
2 Early-age feed restriction	53.02^{b}	389.1^{b}	607.7	824.1	863.1	971.9	3709^{b}
SE	0.04	1.3	6.2	8.5	12.5	11.0	22.0
Significance level[1]	**	**	NS	NS	NS	NS	*
KCl level % B							
1 0.00	--	390.9	595.3	833.2	846.1	939.5	3698
2 0.75	--	393.9	624.5	829.8	897.5	972.0	3811
3 1.50	--	393.6	621.1	820.5	845.8	981.9	3756
4 2.25	--	390.5	622.1	828.8	837.5	936.1	3708
SE	--	1.9	8.8	12.1	17.6	15.6	31.2
Significance level[1]	--	NS	NS	NS	NS	NS	NS
Interaction AB							
T No.							
T1 1×1	--	396.9	617.9	853.4	877.1	944.0	3822
T2 1×2	--	397.5	630.9	838.6	866.6	960.4	3827
T3 1×3	--	396.9	619.2	819.4	828.8	949.9	3747
T4 1×4	--	389.8	626.9	816.5	828.7	917.4	3712
T5 2×1	--	384.8	572.6	812.9	815.1	934.9	3573
T6 2×2	--	390.4	617.9	821.0	928.4	983.7	3794
T7 2×3	--	390.2	623.1	821.6	862.7	1014	3765
T8 2×4	--	391.2	617.2	841.0	846.2	954.8	3703
SE	--	2.7	12.5	17.1	24.9	22.1	44.1
Significance level[1]	--	NS	NS	NS	NS	NS	*
Overall mean	---	392.2	615.7	828.1	856.7	957.4	3743
SE	--	0.94	4.4	6.0	8.8	7.8	15.5

[a-b]: Means in the same column having different superscripts are significantly different at $P \leq 0.05$. [1]: NS= not significant; *= Significant at $P \leq 0.05$; **= Significant at $P \leq 0.01$.

Irrespective of feeding regimen, during the 2nd, 3rd, 4th, 5th and 6th weeks of age, no significant differences were existed in weekly feed intake of chicks due to the effect of dietary KCl level. However, during the period from

0 to 6 weeks of age, erratic differences were observed in cumulative feed intake among groups of chicks, due to the effect of dietary KCl level. During the whole period from 0 to 6 weeks of age, significant ($P \leq 0.05$) differences were observed in feed intake of chicks due to the effect of interaction of feeding regimen by dietary KCl. While, the effects of both the two factors on feed intake were not interrelated during the 2^{nd}, 3^{rd}, 4^{th}, 5^{th} and 6^{th} weeks of age.

Apart from these erratic differences, it appeared that supplemental KCl tended to increase the feed intake of experimental chicks. This result may, at least in part, coincide with those of Smith and Teeter (1987b) and Smith and Teeter (1993) who observed that supplementing drinking water with up to 0.7% KCl elevated the feed consumption of broiler chicks subjected to cyclic or constant heat stress.

Feed conversion ratio (g feed : g gain) of chicks:

Data in Table 5 show that, during the 1^{st} week of age, the average feed conversion ratios were 1.09 and 0.73 for FF- and EFR-chicks, respectively, with significant ($P \leq 0.01$) difference in favour of EFR-chicks. When EFR-chicks returned to *ad libitum* feeding, they also used the feed more efficiently during the 2^{nd} week of age, and exhibited a significantly superior feed conversion (1.58) than FF-chicks (1.72). Thereafter, this significant difference in feed conversion observed between FF- and EFR-chicks disappeared during the 3^{rd}, 4^{th} and 5^{th} weeks of age. Whereas between 5 and 6 weeks of age, EFR-chicks again showed a significantly ($P \leq 0.01$) better feed conversion (2.48) compared with that of FF-chicks (2.80). Moreover, for the entire experimental period from 0 to 6 weeks of age, EFR-chicks displayed a significant ($P \leq 0.01$) improvement in feed efficiency, since they converted the feed at a ratio of 1.98 compared with their FF-counterparts (2.06).

Regardless of feeding regimen, up to the end of the 3^{rd} week of age, there were no significant differences in feed conversion of chicks due to the effect of dietary KCl. Between 3 and 4 weeks of age, chicks fed diets containing 0.75, 1.5 or 2.25% KCl exhibited feed conversions of 1.86, 1.87 and 1.86, respectively, with no significant differences among them, while those fed 0.0% KCl-diet displayed a significantly ($P \leq 0.05$) inferior feed conversion (1.98). Between the 4^{th} and 5^{th} weeks of age, chicks fed 0.75% KCl-supplemented diet converted the feed less efficiently (2.75), and significantly ($P \leq 0.01$) different from those fed 0.0% KCl-diet or those fed 1.5 or 2.25% KCl-supplemented diets. These latter three groups achieved feed conversions of 2.46, 2.33 and 2.28, respectively, with no significant differences among them. At the age interval between 5 and 6 weeks of age, chicks fed on 1.5 or 2.25% KCl-supplemented diets attained feed conversions of 2.40 and 2.31, respectively, with no significant difference between them. At the same age, chicks fed on 0.0% KCl-diet and those fed the 0.75% KCl-supplemented diet exhibited significantly ($P \leq 0.01$) similar feed conversions of 2.96 and 2.82, respectively, which were significantly inferior to those obtained with the other two groups. The same trend of differences in feed conversion was true for the entire period between 0 and 6 weeks of age, where chicks fed diets containing 0.0, 0.75, 1.5, or 2.25% KCl displayed feed conversions of 2.11, 2.08, 1.97 and 1.93, respectively. Analysis of variance showed that, during the 2^{nd}, 3^{rd} and 4^{th} weeks of age, there were no significant differences in feed conversion of chicks due to the effect of interaction of feeding regimen by dietary KCl level. The differences in feed conversion due to this interaction, however, were significant (P≤0.05) during the period from 4-5 and 5-6 weeks of age, but during the whole period of study the differences were significant (P≤0.01).

Table 5: Means and standard errors for feed conversion and mortality rate (%) of experimental chicks.

Treatments	Feed conversion ratio							Mortality
	Chick's age in weeks							
	0-1	1-2	2-3	3-4	4-5	5-6	0-6	Rate, %
Main factors:								
Feeding regimen A								
1 Full feeding	1.094^{b}	1.724^{b}	1.781	1.917	2.480	2.809^{b}	2.060^{b}	6.11
2 Early-age feed restriction	0.725^{a}	1.578^{a}	1.696	1.864	2.432	2.484^{a}	1.983^{a}	2.22
SE	0.01	0.04	0.04	0.02	0.06	0.05	0.01	1.57
Significance level[1]	**	*	NS	NS	NS	**	**	NS
KCl level % B								
1 0.00	--	1.703	1.756	1.978^{b}	2.464^{a}	2.956^{b}	2.108^{b}	10.0^{a}
2 0.75	--	1.601	1.733	1.856^{a}	2.747^{b}	2.820^{b}	2.082^{b}	3.33^{b}
3 1.50	--	1.679	1.734	1.867^{a}	2.328^{a}	2.403^{a}	1.965^{a}	2.22^{b}
4 2.25	--	1.622	1.729	1.860^{a}	2.284^{a}	2.307^{a}	1.930^{a}	1.11^{b}
SE	--	0.05	0.05	0.03	0.08	0.07	0.02	2.22
Significance level[1]	--	NS	NS	*	**	**	**	*
Interaction AB								
T No.								
T1 1×1	--	1.828	1.908	2.046	2.447	3.316	2.223	15.55
T2 1×2	--	1.658	1.722	1.872	3.009	2.995	2.138	4.44
T3 1×3	--	1.768	1.709	1.902	2.194	2.486	1.961	2.22
T4 1×4	--	1.642	1.781	1.847	2.269	2.440	1.918	2.22
T5 2×1	--	1.578	1.603	1.909	2.481	2.597	1.994	4.44
T6 2×2	--	1.544	1.743	1.840	2.484	2.646	2.026	2.22
T7 2×3	--	1.588	1.758	1.831	2.463	2.321	1.970	2.22
T8 2×4	--	1.589	1.678	1.874	2.300	2.374	1.943	0.00
SE	--	0.08	0.08	0.04	0.11	0.09	0.023	3.14
Significance level[1]	--	NS	NS	NS	*	*	**	NS
Overall mean	--	1.651	1.738	1.891	2.456	2.647	2.025	4.16
SE	--	0.029	0.027	0.015	0.039	0.033	0.007	1.11

a-b: Means in the same column having different superscripts are significantly different at P ≤0.05. 1: NS= not significant; *= Significant at P ≤0.05; **= Significant at P ≤0.01.

Some workers observed that early-age feed restriction had no significant effect on feed efficiency of broiler chicks and feed-restricted broilers failed to catch-up in growth as *ad libitum*-fed birds (Pokniak and Cornejo, 1982; and Newcombe *et al*, 1992). However, the present result concurs with those of Plavnik *et al* (1986), Plavnik and Hurwitz (1989), Deaton (1995) and Zhong *et al* (1995) who indicated that body weight of chicks which had been retarded by early feed restriction, upon refeeding reached and sometimes exceeded that of the *ad libitum*-fed birds at market age, with a concomitant improved feed efficiency. Such discrepancies concerning the beneficial effect of early-age feed restriction on the performance of broiler chicks for weight gain and feed conversion, could be attributed to differences in severity and duration of feed restriction, age of chicks at the onset of feed restriction, feed intake during the period of refeeding, and sex or strain of chicks. These factors may affect the subsequent ability of broiler chicks to recover from a growth deficit that occurred during the period of feed restriction (Yu and Robinson, 1992). Furthermore, the present results are in accordance with those of Yahav and Plavnik (1999) and Zulkifli *et al* (2000). They indicated that when the feed of broiler chicks was restricted during the first two weeks of age; to support 50% of normal growth rate or to 60% of *ad libitum* feed intake, respectively, and challenged by a heat stress later in life (5 to 6 weeks of age), the chicks attained similar or heavier body weight compared with *ad libitum*-fed chicks, but with better or similar feed efficiency, respectively. It is worth noting, however, that the feed restriction practiced by Yahav and Plavnik (1999) was applied from 7 to 14 days of age, while Zulkifli *et al* (2000) imposed it on chicks only at 4, 5 and 6 days of age, which may be less severe than that practiced in the present experiment.

It can be concluded that supplemental KCl at a level of 1.5 or 2.25% of the diet equally improved the feed efficiency of chicks. With the same dietary KCl levels (1.5 and 2.25%), significantly heavier body weight, and accelerated growth were achieved by broiler chicks under the conditions of the present study. This conclusion is in a good agreement with those of other workers who reported that supplementation of either drinking water with KCl providing 0.15% K (Teeter and Smith, 1986), or diet with 1.5 or 2% K^+ in the form of KCl (Smith and Teeter, 1987c) improved both weight gain and feed efficiency of broiler chicks reared under conditions of chronic heat stress (35°C) between 5 and 8 weeks of age.

Mortality rate of chicks:

From Table 5, regardless of the absence of significant difference in mortality rate due to the effect of feeding regimen, it was obvious that feed restriction markedly reduced the mortality of chicks in comparison with *ad libitum* feeding, under the conditions of the present study. Irrespective of feeding regimen, significant ($P \leq 0.05$) differences were detected in cumulative mortality rate of chicks, due to the effect of dietary KCl level. Chicks fed diet with no supplemental KCl (0.0% KCl) had the highest mortality rate (10%), and differed significantly in that respect from the other groups of chicks which were fed KCl-supplemented diets. Mortality rates of 3.33, 2.22 and 1.11% were exhibited by chicks fed diets containing 0.75, 1.5 and 2.25% KCl, respectively, with no significant differences among them. Moreover, it appeared that mortality rate of chicks was linearly reduced by increasing dietary KCl level. Analysis of variance revealed that, the effects of feeding regimen and dietary KCl level on mortality rate of the experimental chicks were not interrelated.

Several reports in the literature indicated that the adverse effects of high rearing temperature on broiler chicks included an increase in mortality rate (Squibb and Wogan, 1960; and Reece *et al*, 1972). The present result, however, is in keeping with those reported by Fontana *et al* (1992) who stated that early-age feed restriction significantly reduced the cumulative mortality of broiler chicks. A lower rate of mortality; caused by "Sudden Death Syndrome", was also reported in broilers restricted to 75% of the feed intake of control birds from 5 to 39 days of age (Bowes *et al* , 1988), or restricted from 6 to 27 days of age on an alternative-day feed restriction program (O'Sullivan *et al,* 1991). In addition there is evidence; which may confirm the present result, is demonstrated by Yahav and Plavnik (1999) and Zulkifli *et al* (2000) who indicated that early-age feed restriction during the first two weeks of age reduced the mortality of broiler chicks that were challenged by a heat stress later in life between 5 and 6 weeks of age.

The present result would indicate the beneficial effect of supplementation of the diet with KCl on the viability of broiler chicks grown in hot environment; as is the case of the present experiment. In earlier study, Smith and Teeter (1989) showed that the addition of Na or K-carbonate to the drinking water improved the survival of 4 to 7-week old, heat-stressed broiler chicks. Furthermore, the current result agrees with those of Deyhim and Teeter (1991) and Ait Boulahsen *et al* (1995) who indicated that supplementing the drinking water with KCl at a level up to 0.6% increased the survivability of 5 to 7-week old, heat-stressed broiler chicks.

Carcass traits of experimental chicks:

Data on the effects of feeding regimen and dietary KCl level, and their interaction on relative weights of some selected carcass traits of 6-week-old experimental chicks are summarized in Table 6. The results showed that neither feeding regimen nor dietary KCl level affected the relative weights of eviscerated carcass, giblets, total edible parts or abdominal fat. Consequently, the effects of these two factors on the above-mentioned carcass traits were not interrelated.

This result is in agreement with those of other workers who stated that the effect of early-age feed restriction was not significantly different from that of *ad libitum* feeding on carcass yield, weights of giblets, and abdominal fat, or carcass composition of broiler chicks at marketing age (Fontana *et al,* 1993; Susbilla *et al,* 1994; and Zubair and Leeson, 1994, 1996). However, there are several evidences, indicating that feed restriction during the first two weeks of age reduces the abdominal fat in carcasses of broiler chicks later in life, compared with *ad libitum* feeding (McMurtry *et al,* 1988b, Newcombe *et al,* 1992, and Zhong *et al,* 1995). Other workers; in line with the present results, found no marked change in this respect (Yu *et al,* 1990; Fontana *et al,* 1993; and Zubair and Leeson, 1994, 1996). In contrast to the present result, Plavnik and Yahav (1998) reported that in 8-week old broiler chicks, abdominal fat was significantly lowered in early-age (from 6 to 12 days of age) feed-restricted chicks than *ad libitum*-fed chicks, after exposure to heat stress (25 to 35 °C) between 4 and 8 weeks of age.

Table 6: Means and standard errors for the relative weights (% of live weight) of carcass traits of 6-week-old broiler chicks.

Treatments		Live weight; g	Liver wt. %	Gizzard Wt. %	Heart Wt. %	Giblets Wt. %	Carcass Wt. %	Total edible parts %	Abdominal fat %
Main factors:									
Feeding regimen A									
1 Full feeding		1881	2.13	1.68	0.55	4.36	66.44	70.80	2.45
2 Early-age feed restriction		1931	2.15	1.56	0.53	4.24	66.35	70.59	2.28
SE		45.79	0.04	0.04	0.01	0.08	0.18	0.20	0.20
Significance level[1]		NS	NS	NS	NS	NS	NS	NS	NS
KCl level % B									
1 0.00		1811	2.21	1.69	0.54	4.44	66.39	70.83	2.39
2 0.75		1875	2.19	1.62	0.53	4.34	66.43	70.77	2.41
3 1.50		1972	2.13	1.54	0.56	4.22	66.27	70.49	2.64
4. 2.25		1966	2.02	1.64	0.53	4.20	66.47	70.67	2.05
SE		64.76	0.06	0.07	0.02	0.13	0.25	0.28	0.28
Significance level[1]		NS	NS	NS	NS	NS	NS	NS	NS
Interaction AB									
T No.									
T1	1×1	1759	2.22	1.86	0.60	4.68	66.17	70.85	2.37
T2	1×2	1835	2.13	1.69	0.52	4.35	66.34	70.68	2.42
T3	1×3	1950	2.13	1.53	0.55	4.21	66.27	70.48	2.74
T4	1×4	1978	2.03	1.65	0.52	4.21	66.97	71.18	2.29
T5	2×1	1863	2.19	1.53	0.49	4.21	66.61	70.82	2.40
T6	2×2	1915	2.26	1.53	0.54	4.33	66.53	70.87	2.40
T7	2×3	1993	2.13	1.54	0.56	4.23	66.28	70.51	2.54
T8	2×4	1953	2.02	1.63	0.54	4.19	65.98	70.18	1.81
SE		91.59	0.09	0.09	0.03	0.17	0.36	0.40	0.40
Significance level[1]		NS	NS	NS	NS	NS	NS	NS	NS
Overall mean		1906	2.14	1.62	0.54	4.30	66.39	70.69	2.37
SE		32.38	0.03	0.03	0.01	0.06	0.13	0.14	0.14

[1]: NS = not significant.

Indisputable explanation for these apparent discrepancies cannot be offered. However, since in the present study, feed restriction was imposed on chicks at an earlier age (0-7 days of age) than that practiced by the other workers, and thereafter given free access to *ad libitum* feeding up to 6 weeks of age, one would speculate that this long time interval of full feeding may mask or preclude the depressing effect of early feed restriction on abdominal fat. Thus, although EFR-chicks had lower abdominal fat (2.28%) than their FF- counterparts (2.45%), no significant difference was observed. On the other hand, it is well known that, among the factors which determine the degree of fatness in broilers, energy intake has the predominant effect. Therefore, under hot environmental conditions; as feed intake is generally depressed, a reduction in fat deposition in broiler chicks would be expected. In spite of this acceptable conception, enhanced fatness has been observed in heat-exposed chicks (Ain-Baziz *et al*, 1990; and Geraert *et al*, 1996). Also, Howlider and Rose (1987) found an increase of 0.8 and 1.6% in body lipid content and in abdominal fat proportion in broiler chicks per degree between 21 and 29 °C of rearing temperature. However, decreased growth and an enhanced fatness in heat exposed chicks could seem rather contradictory. A reduction of basal metabolic rate and physical activity of chicks reared at high ambient temperature might spare energy stored as fat. If these conclusions are true, it could be postulated that the depressing effect of early-age feed restriction on abdominal fat deposition in chicks might be obliterated; at least to some extent, under elevated ambient temperatures, as is the case of the present study. On the other hand, the present result is in line with those of Smith and Teeter (1987b); and Smith and Teeter (1992, 1993) who found no differences in dressing percent, and with those of Deyhim and Teeter (1991) who noticed no changes in carcass fat, or with those of Smith (1994) who observed no variations in carcass yield and abdominal fat of heat-stressed broiler chicks given either KCl-supplemented drinking water or tap water.

Economic efficiency of dietary treatments:

It is worth noting that a great variation was observed in cumulative mortality rate (Table 5); where it was significantly increased especially in FF and EFR chicks which received diets with no supplemental KCl. Also, cumulative mortality was higher in chicks of T1 comparing with other treatment groups (T2 to T8) without significant differences. These obvious differences that was observed in cumulative mortality rate will make the economic evaluation for dietary treatments on individuals average basis to be unfair and leading to an erroneous conclusion, hence the comparison will lose its validity. Therefore, it was thought preferably to compare the economic efficiency on treatment-group basis; relying on the final performance of experimental chicks for total weight gain, total feed intake and cumulative feed conversion (Table 7). At the same time, this will display the adverse consequency of high mortality which has a profound impact on profitability; resulting from rearing broiler chicks in hot environmental conditions. Hot environment during the summer season is a major problem for growing broiler chicks, and any improvement in weight gain and survival of chicks would have a positive economic value.

The present results (Table 7) clearly showed beneficial effects of early-age feed restriction, and dietary supplementation with KCl on viability and performance of experimental chicks. The use of early-age feed restriction, and supplemental KCl especially at a level of 1.5 or 2.25%; either singly (T5, and T3 and T4, respectively) or in combination (T7 and T8), reduced the mortality rate, and economically improved the performance of the experimental chicks for weight gain and feed conversion. But because the combination of early-age feed restriction and dietary inclusion of KCl at a rate of 2.25% (T8) significantly improved the viability of chicks as evidenced by no observed mortality, it had the advantages over the other treatments; for the sake of safety and economic use under hot environmental conditions of summer season, as is the case of the present study.

Table 7:Economic efficiency, and performance of 6-week old experimental chicks for total weight gain and cumulative feed conversion on treatment-group basis.

Feeding regimen		Full-feeding (FF)				Early age feed restriction (EFR)			
Supplemental KCl levels %		0.0	0.75	1.50	2.25	0.0	0.75	1.50	2.25
Items / Treatments		T1	T2	T3	T4	T5	T6	T7	T8
Total BW; Kg		67.23^{c}	78.91^{c}	85.94^{a}	87.15^{a}	$79.\ 2^{bc}$	84.51^{ab}	86.28^{a}	87.92^{a}
Total BWG; Kg		65.47^{c}	76.79^{c}	84.04^{a}	85.23^{a}	77.15^{bc}	82.25^{ab}	84.06^{a}	85.77^{a}
Total FI;Kg	Starter	43.64	49.91	50.52	50.56	43.45	46.73	46.89	47.75
	Grower	101.73	114.39	114.25	112.78	110.3	120.24	118.81	118.87
FCR		2.22^{e}	2.13^{d}	1.96^{abc}	1.92^{a}	1.99^{bc}	2.02^{c}	1.97^{abc}	1.94^{ab}
Mortality %		15.55	4.44	2.22	2.22	4.44	2.22	2.22	0.00
Total feeding cost; L.E		113.53	137.06	148.93	158.12	119.75	139.88	149.26	160.79
Price of total 1-day old chicks; L.E (1)		67.50	67.50	67.50	67.50	67.50	67.50	67.50	67.50
Total selling price; L.E (2)		319.35	374.83	408.21	413.97	376.2	401.42	409.84	417.61
Net return; L.E (3)		138.32	170.27	191.78	188.35	188.95	194.04	193.08	189.32
Relative economic efficiency % (4)		100	123.1	138.6	136.1	136.6	140.3	139.6	136.9

(1) Price of one-day old chick was 1.5 L. E.
(2) Selling price of 1 kg live body weight at 6 weeks of age was 4.75 L. E.
(3) Net return = Total selling price of chicks – (Total feeding cost + price of total 1-day old chicks); assuming that other managerial costs are constant.
(4) Relative to that obtained with FF-chicks that fed diet with no supplemental KCl; supposing that this group gave a net return equal to 100%.

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استخدام تحديد العلف المبكر وكلوريد البوتاسيوم لتخفيف الآثار السيئة للإجهاد الحراري علي كتاكيت اللحم

١ـ التأثيرات علي المظاهر الإنتاجية، صفات الذبائح والكفاءة الاقتصادية.

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قسم إنتاج الدواجن ـ كلية الزراعة ـ جامعة المنصورة.

تم إجراء هذه الدراسة بهدف بحث إمكانية تخفيف الآثار السيئة للإجهاد الحراري الذي تتعرض له كتاكيت اللحم خلال فصل الصيف باتباع بعض الوسائل الغذائية وذلك باستخدام إما تحديد العلف في العمر المبكر أو تزويد العلف بكلوريد البوتاسيوم أو جمع الوسيلتين معاً. استخدم عدد ٣٦٠ كتكوت عمر يوم من هجين هبرد. وزعت الكتاكيت عشوائياً إلي نصفين (مجموعتين). وزعت كل مجموعة إلي أربعة معاملات تجريبية. أعطيت الكتاكيت علائق بادئ متماثلة في الطاقة والبروتين من عمر يوم حتى عمر ٢١ يوما ثم أعطيت علائق نامي متساوية في الطاقة والبروتين أيضاً من ٢٢ حتى ٤٢ يوما من العمر. طيور المجموعة الأولي المحتوية علي المعاملات التجريبية ١، ٢، ٣، ٤ غذيت بحرية علي العلائق من عمر يوم حتى نهاية التجربة عمر ٦ أسابيع. طيور المجموعة الثانية المحتوية علي المعاملات التجريبية ٥، ٦، ٧، ٨ تم تحديد العلف لها (٤٠% من الاستهلاك الحر) في الأسبوع الأول فقط وغذيت بحرية بعد ذلك حتى نهاية التجربة (عمر ٦ أسابيع). احتوت العلائق التجريبية (البادئة والناهية) علي ٠,٨% بوتاسيوم طبيعياً من مواد العلف. تم تكوين أربعة علائق تجريبية في فترة البادئ وأربعة علائق في فترة النامي مزودة بأربعة مستويات من كلوريد البوتاسيوم وهي صفر% للمعاملات التجريبية الأولي والخامسة والتي اعتبرت كنترول، ٠,٧٥% للمعاملات التجريبية الثانية والسادسة، ١,٥% للمعاملات التجريبية الثالثة والسابعة، ٢,٢٥% للمعاملات التجريبية الرابعة والثامنة والتي تم التغذية عليها من عمر أسبوع حتى نهاية التجربة (عمر ٦ أسابيع). وبالتالي بعد إمداد العلائق بكلوريد البوتاسيوم أصبح مستوي البوتاسيوم بالعلائق سواء البادئة أو النامية ٠,٨%، ١,٢%، ١,٦% أو ٢,٠% علي الترتيب.

خلال فترة التجربة تم وزن الطيور وتسجيل استهلاك العلف والنفوق وحساب الزيادة الوزنية ومعدل التحويل الغذائي وتم إجراء اختبار ذبح في نهاية التجربة لمعرفة خصائص الذبائح وتم حساب الكفاءة الاقتصادية للعلائق. ويمكن تلخيص أهم النتائج المتحصل عليها في الأتي: ـ تحديد العلف المبكر (خلال الأسبوع الأول) لكتاكيت اللحم لم يؤثر معنوياً في كل من وزن الطيور عند التسويق، الزيادة الوزنية المكتسبة، معدل نفوق الطيور أو صفات الذبائح. لكنه خفض استهلاك العلف و حسن معدل التحويل الغذائي معنوياً. المستويات العالية من كلوريد البوتاسيوم (١,٥ أو ٢,٢٥%) أدت إلي زيادة معنوية في كل من وزن الطيور النهائي، الزيادة الوزنية المكتسبة وحسن معدل التحويل الغذائي وحققت أقل معدل نفوق. أما صفات الذبائح لم تتأثر بمستوى كلوريد البوتاسيوم بالعلائق. تحديد العلف البكر مع إضافة كلوريد بوتاسيوم خاصة المستويات ١,٥ أو ٢,٢٥% بالعلف سواء كل بمفرده أو هما معاً أدي لانخفاض معدل نفوق الطيور وعليه تحسن معدل أداء الطيور ومعدل التحويل الغذائي.استخدام تحديد العلف المبكر مع مستوي ٢,٢٥% كلوريد بوتاسيوم بالغذاء لكتاكيت اللحم أعطت أعلي حيوية وبدون نفوق وهذا يميزها عن المعاملات الأخرى ويجعلها اقتصادية أثناء الجو الحار خلال فصل الصيف كما هو واضح في هذه الدراسة.