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The Effects of Quantitative Feed Restriction and the Protein and L-carnitine Density of Diets on the Performance of Broiler Chickens

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Abstract: The performance of 540 chicks was investigated using a completely randomized design with a 3×3×2 factorial arrangement of treatments. All chicks were fed with an identical diet during day 7 (d_7) until d_{13} of age, but a feed restriction policy was applied so that chicks could receive diets at 100 (100%VFIL), 75 (75%VFIL) and 50 (50%VFIL) percentages of their voluntary feed intake levels. Afterwards, by d_{21} of age, chickens were fed with 6 diets comprising three protein ((NRC., 1993) and as 5 (NRC+5%) and 10 (NRC+10%) percentages higher than NRC recommendation) and two L-carnitine (as zero (ZL) and as 50 mg kg^{-1} (50 L) levels) densities. Chickens were then fed with either ZL or 50L L-carnitine containing diets until day 56 of age. Previously restricted chickens in 75% VFIL and 50% VFIL groups were able to fully recover their body weight by d_{42} and d_{49}, respectively. Compared to their counterparts, chickens in 50%VFIL group had more appropriate ($p<0.05$) FCR during the experiment. Although, chickens in NRC+5% group had higher ($p<0.05$) ADG during d_{13}-d_{21}, but dietary protein and L-carnitine levels had no significant effect on ADG of chickens during the rest of experimental period. Birds in NRC+5% group had relatively ($p>0.05$) lower mortality rate than their counterpart groups. L-carnitine containing diets decreased ($p<0.05$) the abdominal fat pad percentage (AFP%) of chickens. It could be concluded that following to a restriction period, proper energy to protein content diets improve the overall performance of chickens and the addition of L-carnitine to diets in this condition could better reduce the AFP% of broilers.

Key words: Broiler, feed restriction, protein, L-carnitine, density, performance

INTRODUCTION

The genetically improved growth rate and weight gain of broilers associated with higher nutrient requirements during early ages, led to more frequent occurrence of metabolic and skeletal disorders as well as more fat deposited carcass production with higher mortality rates in chickens (Bartov *et al.*, 1974; Griffiths *et al.*, 1977; Leeson and Summers, 1988; Leeson *et al.*, 1991; Tottori *et al.*, 1997; Gonzales *et al.*, 1998). Efforts were made to decrease the incidence of high mortality rates and metabolic disorders in chickens and at the same time, to produce economically favored lean meats in satisfaction of customers (Zhong *et al.*, 1995; Tottori *et al.*, 1997; Urdaneta-Rincon and Lesson, 2002; Bouvarei *et al.*, 2004). Quantitative and qualitative feed restriction policies applied during early age of chicks were reported to lead to improved feed conversion ratios, decreased carcass fat deposition and lowered mortality rates. Different findings were, however, reported in these regards (Plavnik and Hurwitz, 1985; Plavnik *et al.*, 1986; Yu *et al.*, 1990; Plavnik and Hurwitz, 1991; Jones and Farrell, 1992b; Yu and Robinson, 1992; Zubair and Leeson, 1994; Susbilla *et al.,* 2003).

Researches were conducted to find the possible effects of dietary protein and amino acid levels on the performance of broilers under different rearing conditions and diet forms (Maynard and Pesti, 1987; Plavnik and Hurwitz, 1989; Summers *et al.*, 1992; Jones and Farrell, 1992a; Lippens *et al.*, 2002; Eits *et al.*, 2003; Pym *et al.*, 2004). It was shown that increasing dietary protein density or dietary supplementation with lysine or methionine during the refeeding period resulted in inconsistent responses for final body weight and carcass composition of chickens (Jones and Farrell, 1992a; Summers *et al.*, 1992). Increasing methionine in high protein density diets, within the same level of lysine, limited the availability of lysine to stimulate growth (Gas, 2006). Methionine and lysine are together substrates for L-carnitine synthesis (Water and Schaffhauser, 2000).

L-carnitine, a small molecular weight water soluble amine, was well recognized as playing an important role in the mitochondrial oxidation of long-chain fatty acids (Feller and Rudmann, 1998; Water and Schaffhauser, 2000). Several studies have been conducted to determine whether dietary L-carnitine influences the performance

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and carcass composition of broiler chickens, but the results obtained are not in agreement (Rabie and Szilagyi, 1998; Buyse *et al.*, 2001; Lien and Horng, 2001; Kita *et al.*, 2002; Rodehutscord *et al.*, 2002; Xu *et al.*, 2003; Miah *et al.*, 2004). The authors speculated that the improvements in body weight gain in response to an improved utilization of dietary N were achieved through more efficient fat oxidation by L-carnitine. However, Barker and Sell (1994) and Miah *et al.* (2004) reported that dietary L-carnitine had no significant effect on body weight, feed consumption and carcass composition of broilers.

There was no published information showing the possible coexisted effects of quantitative feed restriction policy and the protein and L-carnitine density of diets on the performance of broiler chickens. The main purpose of the present study was, therefore, to find whether increased diet protein density (with same levels of methionine), used immediately after one week restriction period, would enable chickens to fairly compensate their delayed weight gain during refeeding period. L-carnitine was also used to make sure if formerly feed restricted chickens, consumed protein enriched diets immediately after restriction period, would be able to better combust the diet added fats in expense of lean meat production.

MATERIALS AND METHODS

Chickens, diets and management: Six hundred 1-day-old Ross broiler chicks purchased from a commercial hatchery were housed in group cages and fed with a NRC (1993) recommended starter diet from day 1 (d_1) until d_7 of age. At this stage, 540 chicks with uniform average body weight of 101±0.9 g were randomly allocated to one of 18 treatment groups with three replicates and 10 chicks per replicate. The experiment was conducted using a completely randomized design with a 3×3×2 factorial arrangement of treatments so that chickens were fed under different restriction policies with different protein and L-carnitine containing diets as follows: During d_7-d_{13} of age, chicks were fed with an identical protein and energy content starter diet (Table 1) under a feed restriction policy in which chicks could consume feed at 100 (100%VFIL), 75 (75%VFIL) and 50 (50%VFIL) percentages of their voluntary feed intake levels (NRC, 1993). Afterwards, by d_{21} of age, chickens were fed *ad libitum* with six diets from the view point of protein (as NRC 1993 (NRC) and as 5 (NRC+5%) and 10 (NRC+10%) percentages higher than NRC recommendation) and L-carnitine (as zero (ZL) and as 50 mg kg^{-1} (50 L) levels) densities. L-carnitine was used in the form of Carniking® (LONZA Ltd., Basel. Switzerland). Chickens were then fed with either ZL or 50L L-carnitine containing diets until day 56 of age.

During the experimental period, birds were kept in 2.3×1.9 m wire-floored brooding pens placed in a growing broiler house. Area temperature was maintained at 32°C for the first 5 day of experiment and then gradually reduced to 22°C according to the normal management practices applied in broiler rearing systems. Chickens were all vaccinated for Newcastle disease at d_1 and d_{19} and for Gumboro disease at d_{14} of age. The mortality of chickens in treatment groups were recorded during the experimental period.

Table 1: The feed ingredients and the chemical composition of diets used during the day 7 (d_7)-d_{13}, d_{13}-d_{21}, d_{21}-d_{42} and the d_{42}-d_{56} of chickens' age

The feed ingredients and the diet chemical composition	d_7-d_{13} [1]	d_{13}-d_{21} [2,3] NRC	NRC + 5%	NRC + 10%	d_{21}-d_{42} [3]	d_{42}-d_{56} [3]
Feed ingredients (%)						
Shelled corn	57.14	56. 70	52.73	48.94	60.59	65.15
Soybean meal (44% CP)	37.02	37.10	40.19	43.24	31.98	27.54
Yellow Grease	2.20	2.55	3.46	4.29	4.04	4.00
Dicalcium phosphate	1.39	1.39	1.39	1.33	1.28	1.11
Oyster shell	1.34	1.34	1.34	1.34	1.31	1.20
$NaHCO_3$	-	-	-	-	-	0.30
NaCl	0.25	0.25	0.25	0.25	0.25	0.20
Mineral and vitamin premix[4]	0.50	0.50	0.50	0.50	0.50	0.50
DL-methionine	0.16	0.17	0.14	0.11	0.05	-
Total	100.00	100.00	100.00	100.00	100.00	100.00
Calculated Analysis						
Metabolizable energy (ME, Kcal kg^{-1} diet)	2900.00	2900.00	2900.00	2900.00	3025.00	3080.00
Crude protein (CP%)	20.84	20.84	21.88	22.92	18.91	17.33
Calcium (%)	0.91	0.91	0.91	0.91	0.85	0.76
Available phosphorus (%)	0.41	0.41	0.41	0.41	0.38	0.34
Methionine + Cysteine (%)	0.84	0.84	0.84	0.84	0.68	0.54
Lysine (%)	1.09	1.09	1.09	1.09	0.94	0.82

1-Chicks received the same diet at 100, 75 and 50 percentages of their Voluntary Feed Intake Levels (VFIL) during d_7-d_{13} of age. 2-Chickens received diets containing protein as NRC recommended (NRC) and as 5 (NRC+5%) and 10 (NRC+10%) percentages higher than NRC recommended levels during d_{13}-d_{21} of age. 3-L-carnitine was added to chicken diets at Zero Level (ZL) and at 50 mg kg^{-1} level (50 L) during day d_{13}-d_{56} of age. 4-Provided per kg of diet of: vitamin A, 8800 IU; vitamin D_3, 3300 IU; vitamin E, 40 IU; vitamin K_3, 3.3 mg; thiamin, 4.0 mg; riboflavin, 8.0 mg; niacin, 50 mg; panthothenic acid, 15 mg; pyridoxine, 3.3 mg; choline choloride, 900 mg; folic acid, 1 mg; biotin, 0.25 mg; vitamin B_{12}, 0.015 mg; ethoxyquin, 120 mg; manganese, 70 mg; zince, 70 mg; iron, 60 mg; copper, 10 mg; cobalt, 0.1 mg; iodine, 1.0 mg and selenium, 0.3 mg

Measurements and statistical analysis: Feed consumption of chickens was measured daily during the d_7-d_{13} in order to determine their voluntary feed intake during that day and to use it as an indicator for applying feed restriction policies at 100, 75 and 50 percentages of their voluntary feed intake levels for the next day. The *ad libitum* feed intake and the body weight of chickens were measured on d_{13}, d_{21}, d_{42}, d_{49} and d_{56}. Based on these records, the Daily Feed Intake (DFI), Body Weight (BW), Average Daily Gain (ADG) and the Feed Conversion Ratio (FCR) of chickens were calculated. At the end of experiment (d_{56}), all chickens were weighed, slaughtered and chilled overnight. The Dressing Out (DO%), Abdominal Fat Pad (AFP%), Breast Meat (BM%) and the Rump Meat (RM%) percentages of chickens' carcasses were then calculated.

The statistical analysis was accomplished using the general linear model procedure of SAS Statistical Analyzer Software (SAS, 1997). Results were reported based on the mean (±se) values obtained for observations in treatment groups. Differences between the means of observations were considered significant at $p<0.05$ levels. If significant effect of variables was calculated means were contrasted by Duncan's multiple range test (Duncan, 1955). Interaction effects were reported if the differences between the means of observations within the main effects and treatment groups were statistically significant.

RESULTS AND DISCUSSION

Average daily gain: Feed restriction, especially at 50%VFIL, significantly ($p<0.01$) reduced ADG of chickens during d_7-d_{13} (Table 2). After feed restriction period, during d_{13}-d_{21}, chickens in 50%VFIL group had still lower ($p<0.05$) ADG than their counterpart groups. Similar results in weight gain were reported by Lee and Leeson (2001) and Urdaneta-Rincon and Leeson (2002) when broilers were fed with quantitative and qualitative restricted diets from day 1 until day 14 of age. In the present study, 50%VFIL chickens had relatively ($p>0.05$) higher ADG than their counterpart groups during d_{21}-d_{42}, d_{42}-d_{49} and d_{49}-d_{56} of age indicating that both 50%VFIL and 75%VFIL chicken groups could fully recover their body weight during refeeding periods so that chicken in these groups and those in 100%VFIL group performed similar overall ADG for whole experimental period (Table 2). The accelerated growth rate might be associated with relatively lower overall maintenance energy needs in feed restricted chickens compared to that in control group (Yu and Robinson, 1992). In agreement with the results of this study, Lee and Leeson (2001) reported that previously feed restricted broilers could compensate their body weight at day 49 of age.

High protein density diets, used during d_{13}-d_{21} in this study, resulted in a higher ($p<0.05$) ADG in NRC+5% chicken group compared to that in NRC or NRC+10% groups (Table 2). Based on this finding and the results reported by Plavnik and Hurwitz (1989), it could be suggested that the response to amino acids or protein densities in diets, might be maximized during the refeeding period. In agreement with this concept, the relatively improved ($p>0.05$) ADG in NRC+5% and NRC+10% chicken groups, compared to that in NRC group, was continued through to the rest of experimental period (Table 2).

The addition of L-carnitine at a density of 50 mg kg^{-1} of diet had no significant effect ($p>0.05$) on the ADG of broilers in this study. There were even no interaction effects between the main treatment groups in this regard. Xu *et al.* (2003) and Barker and Sell (1994) also reported that adding L-carnitine at levels of 50 or 100 mg kg^{-1} of diets had no imperative effect on the average daily gain of broilers. However, Kita *et al.* (2002) reported that body weight gain of chickens was improved when they received 500 or 1000 mg L-carnitine and 200 or 400 g protein in each kg of diets.

Daily feed intake: As it was expected, during the d_7-d_{13} of experiment, DFI was lower ($p<0.001$) in 50% VFIL and 75% VFIL chicken groups than that in 100% VFIL group. Although this situation was continued through to day 21, but for the rest of experimental duration, (d_{21}-d_{56}), DFI was almost similar in all chicken groups (Table 3). However, for the d_7-d_{56} of experimental period, a lower ($p<0.05$) DFI was recorded for chickens in 50%VFIL group. These results indicate that compared to birds in control (100% VFIL) group, feed restricted chickens, especially those in 50%VFIL group, consumed relatively lower ($p>0.05$) amount of feed per day (Table 3) but ADG was almost similar in all three treatment groups (Table 2). The more appropriate FCR ($p<0.05$) recorded for chickens in 50% VFIL group compared to that in their counterpart groups during d_{13}-d_{21} and through to day 56 of age (Table 4) explains the beneficial of application of feed restriction during the early age of broilers (Plavnik *et al.*, 1986; Fontana *et al.*, 1992; Jones and Farrell, 1992b; Lee and Leeson, 2001; Susbilla *et al.*, 2003)

Dietary protein density affected DFI of chickens (Table 3). During d_{13}- d_{21} of age, chickens in NRC+5% and NRC+10% groups had higher ($p<0.05$) DFI than that in NRC group. This was continued through to d_{21}-d_{42} and the whole 56 days of experiment. This might be due to the relatively sever restricted feeding policy applied during d_7-d_{13} and shows that, during refeeding period, chickens fed with high protein density diets consumed more feed

Table 2: The effects of quantitative feed restriction and the protein and L-carnitine density of diets on the average daily gain (ADG, g/day) of broiler chickens

Main effects	Treatment groups	Experimental periods (age of chickens, day)					
		d_7-d_{13}	d_{13}-d_{21}	d_{21}-d_{42}	d_{42}-d_{49}	d_{49}-d_{56}	d_7-d_{56}
Feed restriction[1]	100% VFIL	18.86±0.40^{a}	35.18±0.51^{a}	50.76±0.75	66.66±1.68	72.50±2.55	49.37±0.58
	75% VFIL	11.80±0.34^{b}	34.76±0.40^{ab}	50.89±0.63	63.21±1.51	75.86±2.80	48.46±0.60
	50% VFIL	6.60±0.30^{c}	33.58±0.41^{b}	52.03±0.74	65.34±2.01	76.91±1.90	48.54±0.57
Protein density[2]	NRC	12.24±1.33	33.67±0.49^{b}	50.46±0.81	64.24±1.94	73.04±2.24	47.89±0.63
	NRC+5%	12.95±1.22	35.23±0.35^{a}	51.38±0.63	64.96±1.96	76.24±2.87	49.21±0.60
	NRC+10%	12.05±1.23	34.61±0.40^{ab}	51.84±0.65	66.00±1.33	75.98±2.23	49.27±0.47
L-carnitine density[3]	ZL	12.56±0.96	34.83±0.41	51.75±0.54	65.31±1.45	76.01±1.97	49.24±0.47
	50 L	12.26±1.08	34.19±0.34	50.70±0.61	64.83±1.42	74.17±2.04	48.33±0.47

1-Chicks received the same diet at 100, 75 and 50 percentages of their Voluntary Feed Intake Levels (VFIL) during d_7-d_{13} of age. 2-Chickens received diets containing protein as NRC recommended (NRC) and as 5 (NRC+5%) and 10 (NRC+10%) percentages higher than NRC recommended levels during d_{13}-d_{21} of age. 3-L-carnitine was added to chicken diets at Zero Level (ZL) and at 50 mg kg^{-1} level (50 L) during day d_{13}-d_{56} of age. ^{abc}Means with different superscripts in the same column within the same treatment groups are significantly different

Table 3: The effects of quantitative feed restriction and the protein and L-carnitine density of diets on the average Daily Feed Intake (DFI, g/day) of broiler chickens

Main effects	Treatment groups	Experimental periods (age of chickens, day)					
		d_7-d_{13}	d_{13}-d_{21}	d_{21}-d_{42}	d_{42}-d_{49}	d_{49}-d_{56}	d_7-d_{56}
Feed restriction[1]	100% VFIL	29.94±0.23^{a}	63.51±1.66^{a}	105.40±1.98	170.07±4.29	208.57±2.50	110.87±1.60^{a}
	75% VFIL	23.13±0.01^{b}	60.25±1.27^{b}	105.94±1.56	165.53±4.00	209.01±3.45	108.00±1.71^{a}
	50% VFIL	15.43±0.01^{c}	56.90±1.19^{c}	105.71±1.58	168.27±3.70	210.07±3.57	104.55±1.51^{b}
Protein density[2]	NRC	22.79±1.43	56.71±1.67^{b}	101.97±1.57^{b}	162.38±2.96	205.15±3.55	104.29±1.47^{b}
	NRC+5%	22.91±1.47	62.78±1.15^{a}	105.50±1.82^{b}	172.83±4.56	210.67±3.22	109.23±1.93^{a}
	NRC+10%	22.81±1.43	61.69±1.24^{a}	109.37±1.22^{a}	186.67±4.00	211.83±2.86	109.91±1.53^{a}
L-carnitine density[3]	ZL	22.80±1.16	60.34±1.44	106.53±1.40	167.54±3.77	209.11±2.73	107.60±1.53
	50 L	22.87±1.17	60.44±0.92	105.19±1.38	168.38±2.64	209.32±2.61	108.02±1.31

1-Chicks received the same diet at 100, 75 and 50 percentages of their Voluntary Feed Intake Levels (VFIL) during d_7-d_{13} of age. 2-Chickens received diets containing protein as NRC recommended (NRC) and as 5 (NRC+5%) and 10 (NRC+10%) percentages higher than NRC recommended levels during d_{13}-d_{21} of age. 3-L-carnitine was added to chicken diets at Zero Level (ZL) and at 50 mg kg^{-1} level (50 L) during day d_{13}-d_{56} of age. ^{abc}Means with different superscripts in the same column within the same treatment groups are significantly different

to perform high weight gains as compensatory growth (Maynard and Pesti, 1987; Leeson *et al.*, 1991; Leeson and Zubair, 1997).

L-carnitine had no significant effect on DFI of chickens which is in agreement with the observations reported by Xu *et al.* (2003) and Barker and Sell (1994). There were significant interaction effects ($p<0.05$) between protein and L-carnitine content of diets on the DFI during d_{13}-d_{21}, so that the lowest (51.55 g day^{-1}) and the highest (63.59 g day^{-1}) DFI were, respectively, recorded for broilers in NRC and NRC+5% groups not receiving L-carnitine in their diets. Kita *et al.* (2002) reported no such interaction effect on the performance of chickens fed diets contained 5, 20 and 40 percentages of protein and 200, 500 and 1000 mg kg^{-1} of L-carnitine.

Feed conversion ratio: An inappropriate ($p<0.05$) FCR was calculated for birds received 50% VFIL compared to that in 75% VFIL or 100% VFIL due to the application of feed restriction during d_7-d_{13} of age (Table 4). However, during d_{13}-d_{21} and through to the end of present experiment, chickens previously fed with 50% VFIL diet performed more appropriate ($p<0.05$) FCR compared to that in their counterpart groups. As reported by Zubair and Leeson (1994), the improvement in FCR for chickens in 50% VFIL group might be due to depression in basal metabolic rate and maintenance requirements of chickens in this group which was associated with smaller body weights during early growth (Table 2) and lower abdominal fat pad contents at the end of experiment (Table 5).

Increased dietary protein density at NRC+5% and NRC+10% levels (Table 4), caused an inappropriate ($p<0.05$) FCR during the d_{13}-d_{21} of broilers' age. However, no significant differences were observed in FCR during the rest of refeeding period. Leeson and Zubair (1997) reported no effect of increasing dietary protein level on the feed conversion ratio of broiler chickens.

In agreement with results of other research works such as Cartwright (1986), Xu *et al.* (2003) and Barker and Sell (1994), the addition of L-carnitine at 50 mg kg^{-1} had no significant effect on FCR of broilers during the whole experimental period (Table 4). An interaction effect of protein and L-carnitine densities of diets on the FCR of chickens was observed when protein enriched diets were applied during d_{13}-d_{21} of experimental period so that the most appropriate FCR (1.51, kg feed: kg gain) and the most inappropriate FCR (1.83, kg feed: kg gain) were, respectively, calculated for NRC and NRC+10% chicken groups receiving no L-carnitine in their diets. This is while Kita *et al.* (2002), reported no such an effect on the feed

Table 4: The effects of quantitative feed restriction and the protein and L-carnitine density of diets on the average Feed Conversion Ratio (FCR) of broiler chickens

		Experimental periods (age of chickens, day)					
Main effects	Treatment groups	d_7-d_{13}	d_{13}-d_{21}	d_{21}-d_{42}	d_{42}-d_{49}	d_{49}-d_{56}	d_7-d_{56}
Feed restriction[1]	100% VFIL	1.60 ± 0.03^{c}	1.81 ± 0.03^{a}	2.09 ± 0.03	2.59 ± 0.12	2.96 ± 0.12	2.25 ± 0.03^{a}
	75% VFIL	2.00 ± 0.06^{b}	1.74 ± 0.04^{a}	2.08 ± 0.03	2.64 ± 0.08	2.85 ± 0.12	2.21 ± 0.03^{a}
	50% VFIL	2.40 ± 0.10^{a}	1.69 ± 0.03^{b}	2.02 ± 0.02	2.60 ± 0.08	2.76 ± 0.09	2.14 ± 0.02^{b}
Protein density[2]	NRC	2.10 ± 0.10	1.69 ± 0.04^{b}	2.17 ± 0.03	2.56 ± 0.07	2.87 ± 0.11	2.17 ± 0.02
	NRC+5%	1.90 ± 0.09	1.79 ± 3.03^{a}	2.20 ± 0.02	2.70 ± 0.01	2.86 ± 0.14	2.21 ± 0.03
	NRC+10%	2.00 ± 0.10	1.80 ± 0.04^{a}	2.26 ± 0.03	2.57 ± 0.08	2.83 ± 0.08	2.22 ± 0.03
L-carnitine density[3]	ZL	1.90 ± 0.06	1.73 ± 0.04	2.05 ± 0.03	2.60 ± 0.07	2.83 ± 0.09	2.19 ± 0.03
	50 L	2.10 ± 0.10	1.76 ± 0.02	2.07 ± 0.02	2.63 ± 0.08	2.88 ± 0.09	2.24 ± 0.02

1-Chicks received the same diet at 100, 75 and 50 percentages of their voluntary feed intake levels (VFIL) during d_7-d_{13} of age. 2-Chickens received diets containing protein as NRC recommended (NRC) and as 5 (NRC+5%) and 10 (NRC+10%) percentages higher than NRC recommended levels during d_{13}-d_{21} of age. 3-L-carnitine was added to chicken diets at zero level (ZL) and at 50 mg kg^{-1} level (50 L) during day d_{13}-d_{56} of age. [abc]Means with different superscripts in the same column within the same treatment groups are significantly different

Table 5: The effects of quantitative feed restriction and the protein and L-carnitine density of diets on the mortality rates and carcass characteristics of broiler chickens

			Carcass characteristics				
Main Effects	Treatment groups	Mortality (%) d_7-d_{56}	Body weight (g)	Dressing out (%)	Abdominal fat (%)	Rump meat (%)	Breast meat (%)
Feed restriction[1]	100% VFIL	4.89 ± 2.00	2546 ± 55	72.40 ± 0.30	3.00 ± 0.10^{a}	29.40 ± 0.20	27.60 ± 0.30
	75% VFIL	5.00 ± 1.98	2503 ± 62	72.00 ± 0.40	2.80 ± 0.20^{ab}	28.90 ± 0.30	27.70 ± 0.30
	50% VFIL	4.56 ± 1.65	2510 ± 54	71.50 ± 0.50	2.60 ± 0.10^{b}	29.00 ± 0.30	28.20 ± 0.20
Protein density[2]	NRC	7.22 ± 2.26	2521 ± 72	72.10 ± 0.40	2.80 ± 0.10	29.30 ± 0.30	27.90 ± 0.30
	NRC+5%	2.78 ± 1.35	2480 ± 55	71.90 ± 0.40	2.80 ± 0.10	28.90 ± 0.20	27.90 ± 0.40
	NRC+10%	4.40 ± 1.85	2558 ± 45	72.00 ± 0.40	2.70 ± 0.10	29.10 ± 0.30	27.70 ± 0.30
L-carnitine density[3]	ZL	3.70 ± 1.20	2521 ± 37	72.10 ± 0.30	3.00 ± 0.10^{a}	29.10 ± 0.20	28.00 ± 0.30
	50 L	5.93 ± 1.80	2519 ± 55	71.90 ± 0.30	2.70 ± 0.10^{b}	29.10 ± 0.20	27.70 ± 0.30

1-Chicks received the same diet at 100, 75 and 50 percentages of their Voluntary Feed Intake Levels (VFIL) during d_7-d_{13} of age. 2-Chickens received diets containing protein as NRC recommended (NRC) and as 5 (NRC+5%) and 10 (NRC+10%) percentages higher than NRC recommended levels during d_{13}-d_{21} of age. 3-L-carnitine was added to chicken diets at Zero Level (ZL) and at 50 mg kg^{-1} level (50 L) during day d_{13}-d_{56} of age. [ab]Means with different superscripts in the same column within the same treatment groups are significantly different

conversion ratio of broiler chickens when different protein (at levels of 5, 20 and 40%) and L-carnitine (at levels of 200, 500 and 1000 mg kg^{-1}) densities were used in the diets of chickens. However, in the present study, there were no such interaction effects during the d_{21}-d_{42} and through to the rest of experimental period.

Mortality rates: Feed restriction had no significant effect on the mortality rates of broilers in this study (Table 5) which is in agreement with the observations reported by Fontana *et al.* (1992), Tottori *et al.* (1997), Gonzales *et al.* (1998) and Lee and Leeson (2001). However, Urdaneta-Rincon and Leeson (2002) reported that when feed restriction was applied, broilers appeared to be able to recover from feed restriction and there was an associated reduction in their mortality rates. Although, increasing dietary protein density had no significant effect on the mortality rates of chickens in present study (Table 5), but, increasing dietary protein, especially at NRC+%5 level, could numerically decrease the mortality occurrences in broilers. L-carnitine had no significant effect on the mortality rates of chickens in this study which is in agreement with the results of Barker and Sell (1994) and Buyse *et al.* (2001).

Carcass characteristics: The DO% of broilers was not affected by feed restriction policy or the protein and L-carnitine densities of diets (Table 5). Leeson and Zubair (1997), Urdaneta-Rincon and Leeson (2002) and Xu *et al.* (2003) also found no differences between carcass weights of broilers.

The AFP% of chickens was decreased ($p<0.05$) with the feed restriction policy so that the lowest AFP% was recorded for broilers in 50% VFIL group (Table 5). This suggests that increasing feed restriction will lead to depression in the rate of *de novo* lipogenesis in broilers (Fontana *et al.*, 1993). Dietary protein levels had no significant effect on the AFP% of chickens, but broilers in NRC+%10 group had slightly lower AFP% than their counterpart groups. Plavnik and Hurwitz (1989) also demonstrated such an effect on the abdominal fat pad of broilers fed with diets containing protein higher than NRC recommendations. Similar to the reports of Cartwright (1986), Rabie and Szilagyi (1998) and Xu *et al.* (2003), also in this study the AFP% of chickens were significantly ($p<0.05$) decreased with the addition of L-carnitine to diets (Table 5). There were significant interaction effects ($p<0.05$) between feed restriction, dietary protein and L-carnitine densities on the AFP% of broilers in the present study so that the highest depression in AFP% was obtained by chickens in 50% VFIL fed with protein at NRC+10% and L-carnitine at 50 mg kg^{-1} levels. Rodehutscord *et al.* (2002) found not such an interaction effect when feed restriction was applied using L-carnitine at zero or 80 mg kg^{-1} of broilers' diets.

Although the RM% and BM% of broilers were not significantly affected by feed restriction or the protein and L-carnitine content of diets, but BM% of broilers tended to relatively increase with increasing intensity of feed restriction (Table 5). Lee and Lesson (2001) also reported that breast meat percentages of broilers were improved with increasing their feed restriction.

CONCLUSIONS

It can be expressed that the most consistent result of applying a period of feed restriction in early age of chicks is, somehow, an improvement in overall feed conversion ratio and a reduction in abdominal fat pad contents of broilers. The increasing of dietary protein density is effective in improving broiler performances if an appropriate ratio of energy to protein level in diets is applied. Adding L-carnitine to broiler diets might also be more beneficial in this condition. Mortality rates seems to be declined if protein enriched diets are applied immediately after application of a feed restriction policy. Further research works are, however, suggested to be done in these regards.

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