Effect of Age of Feed Restriction and Microelement Supplementation to Control Ascites on Production and Carcass Characteristics of Broilers

M. A. Camacho, M. E. Suárez,[1] J. G. Herrera, J. M. Cuca, and C. M. García-Bojalil

Colegio de Postgraduados, Programa de Ganadería, Montecillo, Texcoco, Mexico 56230

ABSTRACT Three experiments were conducted, from January until September 2001, to estimate the optimized age to apply feed restriction to control mortality from ascites, with no negative effects on production and carcass characteristics of broilers. For each experiment, 1,200 1-d-old mixed Ross × Peterson chicks were reared in floor pens (50 chicks in each) and fed commercial feed. Feed restriction was applied for 8 h/d for 14 d at 21 or 28 d of age in experiment 1, 14 or 21 d in experiment 2, and 7 or 14 d in experiment 3. In experiments 2 and 3, a microelement supplement (without or with) was tested; the control groups received feed ad libitum and no supplement. Body weight gain, feed conversion, total mortality, and mortality from ascites, leg problems, and carcass characteristics were considered at the end of each experiment. The data were analyzed as a completely randomized design, or as a 2 × 2 factorial to estimate main and interaction effects (experiments 2 and 3). Additional analyses, including the control, were done; means comparisons were by orthogonal contrasts. The production and carcass characteristics of the restricted groups were lower than the control but were not statistically different in experiments 2 and 3, although the optimized age for feed restriction was at 7 d. Total mortality and mortality from ascites decreased by restriction, but leg problems increased without supplement. The results indicated that quantitative feed restriction and microelement supplementation at 7 d of age reduced mortality from ascites and leg problems and permitted compensatory growth sufficient to equal the production characteristics of the control group at 49 d of age. However, it is necessary to determine the specific microelements to be supplemented and to estimate the effects of season and genetic line.

(*Key words*: ascites, carcass, compensatory growth, feed restriction, microelement supplement)

2004 Poultry Science 83:526–532

INTRODUCTION

Ascites continues to be one of the main problems in broiler production because of the high mortality rate and the difficulties to control all the factors involved. Among the factors that have been related to ascites are incubation conditions (Camacho and Suárez, 1996a), shell quality (Camacho and Suárez, 1996b), altitude (McGovern et al., 2000), environmental temperature (Wideman et al., 1995; Ruiz-Feria et al., 2001), and growth rate of the birds. Broiler growth rate has been found to have a direct relationship with susceptibility to ascites; to reduce ascites, qualitative and quantitative feed restriction has been used. Newcombe et al. (1992) and Romero et al. (1999) indicated that the levels of triiodothyronine (T3) decrease in feed-restricted broilers, suggesting a lower metabolic rate during restriction. However, Luger et al. (2001) stated that a high growth rate is not always related to the development of ascites.

Mortality from ascites is reduced with feed restriction, but BW and yield of certain parts of the carcass of restricted birds are lower than those of the control groups (Leeson et al., 1992, 1996; Acar et. al., 1995). These effects have not been consistent and probably indicate that these variables depend on other factors, such as the birds pulmonary ventilation rate ability (González-Alvarado et al., 2000), intensity of restriction (Suárez and Rubio, 1989), flock management (Mollison et al., 1984; Arce et al., 1992; Acar et al., 1995), and age of the birds (Robinson et al., 1992).

The literature indicates that the age at which feed restriction programs are applied and their duration and intensity have not been optimized for compensatory growth of feed-restricted birds (Deaton, 1995; McGovern et al., 1999). Therefore, the objective of this study was to evaluate the optimized age at which quantitative feed restriction should be applied to control mortality from ascites and compensatory growth of the restricted birds to equal the production and carcass characteristics of the birds fed ad libitum at the end of the growing period.

MATERIALS AND METHODS

General Procedures

Three experiments were conducted from January until September 2001 in the Experimental Unit of the Colegio

Received for publication August 21, 2002.
Accepted for publication October 24, 2003.
[1]To whom correspondence should be addressed: chontal@colpos.mx.

TABLE 1. Ingredients of commercial diets used in experiments 1, 2, and 3

Ingredient	Starter[1]	Finisher[2]
	(%)	
Sorghum	60.40	66.49
Soybean meal (45% CP)	30.00	24.00
Fish meal	4.00	3.00
Vegetable oil	3.00	3.75
Calcium carbonate	0.84	0.79
Dicalcium phosphate	0.71	1.15
Salt	0.32	0.35
DL-Methionine	0.18	0.12
L-Lysine HCl	0.15	—
Vitamin-mineral[3] premix	0.35	0.30
Coccidiostat	0.05	0.05
Calculated nutrient content		
Crude protein	22	18
Metabolizable energy (kcal/kg)	3,071	3,019
Fat	5.92	7.30
Calcium	0.96	0.95
Available phosphorus	0.42	0.42
Methionine	0.44	0.34
Lysine	1.25	0.96

[1]Starter feed was given from 1 to 28 d.

[2]Finisher feed was given from 29 to 49 d.

[3]Content per kilogram of feed: vitamin A, 8,500 IU; vitamin D_3, 15 IU; vitamin E, 15 IU; choline, 900 mg; menadione S.B., 2.5 mg; thiamine mononitrate, 1 mg; riboflavin, 6 mg; niacin, 40 mg; D-calcium pantothenate, 10 mg; HCl pyridoxine, 1,500 mg; folic acid, 0.5 mg; biotin, 0.05 mg; vitamin B_{12}; 0.01 mg; Mn, 90 mg; Zn, 80 mg; Fe, 50 mg; Cu, 7 mg; I, 1.5 mg; and Se, 0.2 mg.

TABLE 2. Composition of the commercial premix of microelements used in experiments 2 and 3

Nutrient	Content
Threonine, g	0.16
Choline, g	0.60
Vitamin B_{12}, mg	0.014
Phosphorus, g	2.73
Calcium, g	6.27
Antioxidant, g	0.12
Sodium 39 % + chlorine 60%, g	2.45
Biotin, mg	0.080
Lysine HCl, g	1.08
Methionine, g	1.99
Niacin, g	0.04
Zinc, g	0.11
Copper, g	0.01
Iron, g	0.10
Vitamin D_3, UI	2,500,000
Vitamin B_6, g	0.003
Vitamin E, UI	18,000
Pantotheic acid, g	0.01
Vitamin A, UI	9,000,000
Vitamin B_1, g	0.002
Folic acid, mg	0.70
Iodine, mg	0.45
Vitamin K_3, g	0.004
Magnesium, g	0.09
Vitamin B_2, g	0.055
Selenium, mg	0.0004

de Postgraduados, Montecillo, Mexico, located at an altitude of 2,240 m. For each experiment 1,200 mixed-sex, 1-d-old, Ross × Peterson chicks from a commercial hatchery were randomly allocated to one 2.5- × 2.0-m floor pen of 50 chicks each, which was considered the experimental unit. The birds were reared until 49 d of age on oat straw litter, and the house temperature was controlled until the fourth week by thermostatically controlled brooders starting at 32°C and gradually decreased by 2°C per week. After the fourth week, and until the end of the experiment, the average maximum and minimum of temperature inside the house was 22 and 16°C for experiments 1 and 2 and 27 and 18°C for experiment 3. All birds, including the controls, were fed with a commercial feed (Table 1). A starter feed was supplied from 1 to 28 d of age, and finisher was supplied from 29 to 49 d. Water was provided ad libitum, and incandescent light was used to provide 24 h of light throughout the experimental period.

The variables considered at the end of each experiment were BW gain, feed conversion, total mortality, mortality from ascites, leg problems, and carcass characteristics. Live BW and feed consumption were recorded manually as the average of the whole group from each experimental unit at the beginning, before and after restriction, and at the end of each experiment to estimate weight gain and feed conversion. Mortality from ascites was determined by necropsy of the dead birds, and leg problems were estimated visually on chicks that were prostrated or had difficulty walking. Both variables were recorded as the percentage of the total number of the dead birds or total birds in each experimental unit.

At the end of experiments 2 and 3, one male and one female from each pen were selected randomly, deprived of feed for 24 h, weighed, and killed by cervical dislocation. Then, the weights of carcass, breast with bone, thigh with leg, and abdominal fat were recorded. The breasts and legs were cut lengthwise several times to find petechiae caused by capillary rupture.

Feed Restriction

A quantitative feed restriction program was applied 8 h/d for 14 d at different ages. In experiment 1, feed was restricted at 21 or 28 d of age, in experiment 2 at 14 or 21 d, and experiment 3 at 7 or 14 d. In all the experiments the feeders were raised at 0800 h and lowered at 1600 h. Due to the high incidence of leg problems in experiment 1, a restriction plus 10% of microelement supplementation was tested (Table 2) in experiment 2. This percentage was based on the difference between the control and restricted groups on feed consumption in experiment 1. Results for BW and feed conversion showed negative effects due to the supplement. Therefore, in experiment 3 it was reduced to 5%. The supplement was mixed with the available feed, and the control groups did not receive any placebo.

Statistical Analyses

Each experiment was analyzed independently. The data were analyzed by the GLM procedure of the SAS software (SAS Institute, 1994). For experiment 1, data were analyzed as a completely random design with 3 treatments and 8 replications. For experiments 2 and 3

TABLE 3. Least square means for weight gain (WG), feed conversion (FC), total mortality (TM), mortality from ascites (AM), and leg problems (LP) of mixed-sex, 7-wk-old broilers under feed restriction[1] at different ages; experiment 1

Treatment[1]	WG (g)	FC	TM (%)[2]	AM (%)[2]	LP (%)[2]
Control (1)	2,170	2.23	11.15	7.72	4.95
Restriction at 21 d[2] (2)	2,082	2.48	7.47	5.39	20.20
Restriction at 28 d[3] (3)	1,985	2.35	9.19	6.13	21.83
SEM	32.56	0.04	0.04	0.02	0.04
	Significance level				
Orthogonal contrast					
1 vs. 2 + 3	**	**	NS	*	**
2 vs. 3	*	*	NS	NS	NS

[1]Numbers in parentheses used for orthogonal contrasts.

[2]Eight hours per day during the restriction period.

[3]Percentages transformed into arc sine $\sqrt{y}$.

$*P < 0.05$; $**P < 0.01$.

as 2 × 2 factorials with 5 replications and considering age of restriction and supplement (with or without) as main effects. To estimate main effects and their interactions, data were analyzed without the control groups. To compare the treatments of the factorial arrangement with the control groups, additional analyses were performed considering treatment as source of variation (Littell et al., 1991). The variables estimated as percentages were transformed to the arc sine $\sqrt{Y}$ function before the analysis (Steel and Torrie, 1980). Live BW was used as covariate for the analysis of carcass weight and carcass weight as covariate for the analyses of breast, leg, and fat weights. Because both covariates were highly significant, adjusted least square means were estimated. Comparisons of least square means of the control group vs. other treatments were done by orthogonal contrasts. The results are reported as percentages and adjusted least square means. Probabilities less than 5 and 1% were considered significant and highly significant, respectively.

RESULTS AND DISCUSSION

The results of experiment 1 (Table 3) indicated that the control group had a significantly higher performance than the restricted groups, including the frequency of leg problems. Total mortality and mortality from ascites were decreased by restriction but were not different ($P < 0.05$) from the control.

The analysis of the factorial structure for experiments 2 and 3 (Tables 4 and 5) indicated that main effects of age of restriction, supplementation, and their interactions were not significant on production and carcass variables; BW gain and feed conversion improved in birds restricted at an earlier age (2.06 vs. 2.13 at 14 or 21 d of age in experiment 2; 2.14 vs. 2.23 at 7 or 14 d of age in experiment 3) but decreased in those that received the supplement (Tables 4 and 5). The greatest efficiency was achieved in experiment 2 with feed restriction without supplement. This effect was consistent in experiment 3, which could indicate that the supplement affected negatively feed consumption and, therefore, weight gain and feed conversion.

Total mortality was not different among treatments, but mortality from ascites decreased significantly (51.58%) as a result of feed restriction and 5% of supplement (experiment 3). Leg problems showed an inverse relationship with age of restriction. They increased by effect of feed restriction but decreased with supplement.

The analyses including the control groups indicated that weight gain in the restricted groups was not different from the control groups, but for the restricted groups at 7 d of age without supplement (Tables 6 and 7) this variable was 34 g higher than the control; feed conversion was better with feed restriction (2.31 vs. 2.19 for control and restricted birds, respectively). Total mortality and mortality from ascites decreased in feed-restricted birds without supplement in experiment 2; however, a positive effect of restriction plus supplementation was observed in the results of experiment 3 on total mortality (12.71 vs. 6.56%) and mortality from ascites (7.29 vs. 3.75%). In all of the experiments, leg problems increased more than 50% in the restricted groups without microelement supplementation.

Carcass, thigh and leg, and abdominal fat weights of the restricted groups were not different from those of the control groups in any of the experiments. Feed restriction at 7 d of age was more favorable for carcass weight (experiment 3), and breast weight of these birds was 69 g higher than of control birds. The birds with greater breast weights had also lower leg weights.

The results of this study showed that the age at which quantitative feed restriction was applied was an important factor to control mortality from ascites and compensatory growth of the restricted chickens. In experiment 1, in which the birds were restricted at 21 or 28 d of age, there was not sufficient compensatory growth to equal the final BW of the control group. In experiments 2 and 3 in which the birds were restricted at 7 and 14 d of age, the difference in weight gain of the restricted groups was very small, and some of the groups were able to surpass the BW of the control groups. This result

TABLE 4. Least square means and analysis of variance for weight gain (WG), feed conversion (FC), total mortality (TM), mortality from ascites (AM), leg problems (LP), carcass weight (CW), breast weight (BRW), leg and thigh weight (LTW), and abdominal fat weight (AFW) of mixed-sex, 7-wk-old broilers under feed restriction[1] plus microelements[2] at different ages; experiment 2

Effect	Production variable					Carcass variable (g)			
	WG (g)	FC	TM (%)[3]	AM (%)[3]	LP (%)[3]	CW[4]	BRW[5]	LTW[5]	AFW[5]
Age of restriction									
Restriction at 14 d	2,275	2.06	14.01	9.19	5.05	1,895	487	453	37
Restriction at 21 d	2,198	2.13	13.75	9.13	7.68	1,962	502	495	44
SEM	45.49	0.04	0.03	0.03	0.02	70.36	16.94	20.90	2.81
Supplement of microelements									
Without supplement	2,270	2.05	12.24	8.12	7.75	1,931	495	473	43
With supplement	2,203	2.17	15.52	10.21	5.00	1,926	494	475	38
SEM	45.49	0.04	0.03	0.03	0.02	70.36	16.94	20.90	2.81
Age of restriction × supplement of microelements									
Restriction at 14 d without supplement	2,304	1.99	10.94	7.56	6.67	1,869	481	438	36
Restriction at 21 d without supplement	2,236	2.06	13.54	8.68	9.17	1,992	508	508	49
Restriction at 14 d with supplement	2,247	2.12	17.09	10.83	3.33	1,921	492	468	37
Restriction at 21 d with supplement	2,160	2.21	13.96	9.52	6.67	1,931	495	482	38
SEM	60.65	0.06	0.04	0.04	0.03	99.50	23.96	29.56	3.98
	Significance level								
Analysis of variance									
Age of restriction	NS	NS	NS	NS	*	NS	NS	NS	NS
Supplement of microelements	NS	NS	NS	NS	*	NS	NS	NS	NS
Age of restriction × supplement of microelements	NS	NS	NS	NS	NS	NS	NS	NS	NS

[1]Eight hours per day during the restriction period.
[2]Supplement = 10% microelement content of the diet.
[3]Percentages transformed into arc sine $\sqrt{y}$.
[4]Ajusted to a final BW of 2,075 g.
[5]Ajusted to a carcass weight of 1,933 g.
*$P < 0.05$; **$P < 0.01$.

TABLE 5. Least square means and analysis of variance for weight gain (WG), feed conversion (FC), total mortality (TM), mortality from ascites (AM), leg problems (LP), carcass weight (CW), breast weight (BRW), leg and thigh weight (LTW), and abdominal fat weight (AFW) of mixed-sex, 7-wk-old broilers under feed restriction[1] plus microelements[2] at different ages; experiment 3

Effect	Production variable					Carcass variable (g)			
	WG (g)	FC	TM (%)[3]	AM (%)[3]	LP (%)[3]	CW[4]	BRW[5]	LTW[5]	AFW[5]
Age of restriction									
Restriction at 7 d	2,339	2.14	6.04	3.86	2.50	2,281	563	508	45
Restriction at 14 d	2,269	2.23	7.08	3.65	6.04	2,283	538	506	49
SEM	21.47	0.02	0.03	0.02	0.04	71.69	15.27	19.28	3.10
Supplement of microelements									
Without supplement	2,320	2.17	7.92	4.48	6.25	2,338	574	510	49
With supplement	2,288	2.21	5.21	3.02	2.29	2,226	527	504	46
SEM	21.47	0.02	0.03	0.02	0.04	71.69	15.27	19.28	3.10
Age of restriction × supplement of microelements									
Restriction at 7 d without supplement	2,356	2.15	7.50	4.79	3.54	2,367	588	504	44
Restriction at 14 d without supplement	2,284	2.19	8.33	4.17	8.96	2,195	538	512	46
Restriction at 7 d with supplement	2,322	2.14	4.58	2.92	1.46	2,308	560	516	53
Restriction at 14 d with supplement	2,254	2.27	5.83	3.13	3.13	2,257	516	496	45
SEM	30.37	0.03	0.04	0.03	0.05	101.38	21.60	27.27	4.39
	Significance level								
Analysis of variance									
Age of restriction	NS	NS	NS	NS	*	NS	NS	NS	NS
Supplement of microelements	NS	NS	NS	NS	*	NS	*	NS	NS
Age of restriction × supplement of microelements	NS	NS	NS	NS	NS	NS	NS	NS	NS

[1]Eight hours per day during the restriction period.
[2]Supplement = 5% microelement content of the diet.
[3]Percentages transformed into arc sine $\sqrt{y}$.
[4]Ajusted to a final BW of 2,579 g.
[5]Ajusted to a carcass weight of 2,285 g.
*$P < 0.05$; **$P < 0.01$.

TABLE 6. Least square means for weight gain (WG), feed conversion (FC), total mortality (TM), mortality from ascites (AM), leg problems (LP), carcass weight (CW), breast weight (BRW), leg and thigh weight (LTW), and abdominal fat weight (AFW) of mixed-sex, 7-wk-old broilers under feed restriction[1] plus microelements[2] at different ages; experiment 2

	Production variable					Carcass variable (g)			
Treatment	WG (g)	FC	TM (%)[4]	AM (%)[4]	LP (%)[4]	CW[5]	BRW[6]	LTW[6]	AFW[6]
Control (1)	2,307	2.13	16.46	11.67	4.58	1,950	511	488	35
Restriction at 14 d without supplement (2)	2,304	1.99	10.94	7.56	6.67	1,869	481	438	36
Restriction at 21 d without supplement (3)	2,236	2.06	13.54	8.68	9.17	1,992	508	508	49
Restriction at 14 d with supplement (4)	2,247	2.12	17.09	10.83	3.33	1,921	492	468	37
Restriction at 21 d with supplement (5)	2,160	2.21	13.96	9.52	6.67	1,931	495	482	38
SEM	45.49	0.04	0.03	0.03	0.02	70.36	16.94	20.90	2.81
					Significance level				
Orthogonal contrast									
1 vs. 2 + 3 + 4 + 5	NS	NS	NS	NS	NS	NS	NS	NS	NS
2 + 4 vs. 3 + 5	NS	NS	NS	NS	*	NS	NS	NS	NS
2 vs. 4	NS	NS	*	NS	*	NS	NS	NS	NS
3 vs. 5	NS	NS	NS	NS	NS	NS	NS	NS	NS

[1]Eight hours per day during the restriction period.
[2]Supplement = 10% microelement content of the diet.
[3]Numbers in parentheses used for orthogonal contrasts.
[4]Percentages transformed into arc sine $\sqrt{y}$.
[5]Ajusted to a final BW of 2,075 g.
[6]Ajusted to a carcass weight of 1,933 g.
*$P < 0.05$; **$P < 0.01$.

indicated that restriction at 7 d of age, for 8 h/d (which allowed about 7% less feed consumption than the control groups) and for 14 d, enabled the birds to attain the required compensatory growth to equal the live BW of the nonrestricted chickens. These results were similar to those obtained by Acar et al. (1995) with broilers restricted in the consumption of metabolizable energy at 7 to 14 d of age. However, the same authors also reported that the birds restricted from 4 to 11 d of age had the lowest final BW. This finding possibly indicates a critical stage during the first week of life because of the influence of dietary composition (Noy and Sklan, 2002), higher requirements to maintain a high metabolic rate (Leeson, 1996), or a lower physiological limit for quantitative feed restriction. Plavnik and Hurwitz (1988) suggested that feed restriction should be between 5 and 7 d of age, and the results of experiment 3 are in agreement with this recommendation.

Feed conversion was better in most of all the restricted groups, although the difference from the control groups was significant only in experiment 3. This improvement in

TABLE 7. Least square means for weight gain (WG), feed conversion (FC), total mortality (TM), mortality from ascites (AM), leg problems (LP), carcass weight (CW), breast weight (BRW), leg and thigh weight (LTW), and abdominal fat weight (AFW) of mixed-sex, 7-wk-old broilers under feed restriction[1] plus microelements[2] at different ages; experiment 3

	Production variable					Carcass variable (g)			
Treatment[3]	WG (g)	FC	TM (%)[4]	AM (%)[4]	LP (%)[4]	CW[5]	BRW[6]	LTW[6]	AFW[6]
Control (1)	2,322	2.31	12.71	7.29	2.71	2,298	574	531	49
Restriction at 7 d without supplement (2)	2,356	2.15	7.50	4.79	3.54	2,367	588	504	44
Restriction at 14 d without supplement (3)	2,284	2.19	8.33	4.17	8.96	2,195	538	512	46
Restriction at 7 d with supplement (4)	2,322	2.14	4.58	2.92	1.46	2,308	560	516	53
Restriction at 14 d with supplement (5)	2,254	2.27	5.83	3.13	3.13	2,257	516	496	45
SEM	30.37	0.03	0.04	0.03	0.05	101.38	21.60	27.27	4.39
Orthogonal contrast					Significance leve				
1 vs. 2 + 3 + 4 + 5	NS	*	**	**	NS	NS	NS	NS	NS
2 + 4 vs. 3 + 5	*	NS	*	NS	**	NS	*	NS	NS
2 vs. 4	NS	NS	NS	NS	NS	NS	NS	NS	NS
3 vs. 5	NS	NS	NS	NS	**	NS	NS	NS	NS

[1]Eight hours per day during the restriction period.
[2]Supplement = 5% microelement content of the diet.
[3]Numbers in parentheses used for orthogonal contrasts.
[4]Percentages transformed into arc sine $\sqrt{y}$.
[5]Ajusted to a final BW of 2,579 g.
[6]Ajusted to a carcass weight of 2,285 g.
*$P < 0.01$; **$P < 0.05$.

feed efficiency was not consistent in all of the experiments despite of the fact that the severity and the duration of the restriction were similar. Zubair and Leeson (1994) pointed out that during restriction body mass is reduced, and, consequently, energy requirements are decreased.

The results for mortality from ascites are in agreement with those reported by Arce et al. (1992, 1995) under similar conditions of management and altitude. In this study, the effect of the age at which feed was restricted was observed, as well as the positive effect of the 5% microelement supplementation on total mortality and mortality from ascites.

Leg problems increased significantly in the restricted groups according to the age at which feed restriction was applied. This result was not in agreement with reports indicating that feed restriction reduces dyscondroplasia (Yu and Robinson, 1992; Elliot and Edwards, 1994; Edwards, 2000) as an effect of muscle weight reduction and, consequently, BW. In experiment 1, the restricted groups weighed less than the control group. Leg problems in broilers have been attributed to several causes, including genetics and nutrition (Sullivan, 1994), speed of growth, and imbalance between BW and bone development (Julian, 1998). Edwards (2000) pointed out that broilers fed diets with concentrations of vitamins, minerals, and amino acids lower than their requirements can be more susceptible to leg problems. He recommended the use of quantitative feed restriction, as long as Ca and P were adequately balanced or in excess.

In the present study, feed consumption of the restricted groups was reduced about 7%, including consumption of microelements essential for bone development, mainly vitamin D_3, Ca, P, Zn, Cu, and others. The deficiency of essential microelements could explain the high incidence of leg problems in the restricted groups without the microelement supplement during restriction. This finding was corroborated by the results from the groups that received 5% of supplement containing amino acids, vitamins, and minerals. In these groups, leg problems decreased significantly, even though the BW of the restricted birds were similar to or greater than those of the control groups. Breast and thigh quality were better in feed-restricted birds, which did not exhibit petechiae or bruises from the rupture of capillaries found in the control group (visual observation); however, this characteristic was not analyzed.

Under the experimental conditions of this study, the results indicated that quantitative feed restriction, beginning at 7 d of age with a microelement supplement to compensate for microelements that the birds consume less during restriction, reduced total mortality, mortality from ascites, and leg problems in broilers and permitted a compensatory growth response of the restricted birds great enough to equal the production and carcass characteristics of the control groups at 49 d of age. Nonetheless, it is necessary to conduct further research to determine the repeatability of these results considering the specific microelements to be supplemented and other factors such as the season of the year during which the chickens are reared and their genetic lines.

ACKNOWLEDGMENTS

The authors thank Malta Cleyton de México (México, D.F.) for partial support for this study.

REFERENCES

Acar, N., F. G. Sizemore, G. R. Leach, R. F. Wideman, Jr., R. L. Owen, and G. F. Barbato. 1995. Growth of broiler chicken in response to feed restriction regimens to reduce ascites. Poult. Sci. 74:833–843.

Arce, J., M. Berger, and C. López-Coello. 1992. Control of ascites syndrome by feed restriction techniques. J. Appl. Poult. Res. 1:1–5.

Camacho, E., and M. A. Suárez-Oporta. 1996a. Relación entre enfriamiento y altitud durante la incubación y ascítis. Page 9 in Reunión Nacional de Investigación Pecuaria Morelos. Cuernavaca, Morelos, México.

Camacho, E., and M. A. Suárez-Oporta. 1996b. Características del cascarón de huevo y su relación con ascítis. Page 10 in Reunión Nacional de Investigación Pecuaria Morelos. Cuernavaca, Morelos, México.

Deaton, J. W. 1995. The effect of early feed restriction on broiler performance. Poult. Sci. 74:1280–1286.

Edwards, H. M., Jr. 2000. Nutrition and skeletal problems in poultry. Poult. Sci. 79:1018–1023.

Eliot, M. A., and H. M. Edwards, Jr. 1994. Effect of genetic strain, calcium, and feed withdrawal on growth, tibial dyschondrosplasia, plasma 25-hydroxycholecalciferol in sixteen-day-old chickens. Poult. Sci. 73:509–519.

González-Alvarado, J. M., M. E. Suarez-Oporta, A. Pro-Martınez, and C. López-Coello. 2000. Restricción alimenticia y ́ salbutamol en el control del síndrome ascítico en pollos de engorda: 1. Comportamiento productivo y características de la canal. Agrociencia 34:283–292.

Julian, R. J. 1998. Rapid growth problems: ascites and skeletal deformities in broilers. Poult. Sci. 77:1773–1780.

Leeson, S., J. D. Summers, and L. J. Caston. 1992. Response of broilers to feed restriction or diet dilution in the finisher period. Poult. Sci. 71:2056–2064.

Leeson, S., L. Caston, and J. D. Summers. 1996. Broiler response to energy or energy and protein dilution in the finisher diet. Poult. Sci. 75:522–528.

Leeson, S. 1996. Regulación del crecimiento en pollo de engorda y composición de la canal. Pages 58–62. In: XII Ciclo de conferencias internacionales sobre avicultura, AMENA. Guadalajara, Jalisco, México.

Littell, R. C., R. J. Freund, and P. C. Spector. 1991. SAS System for Linear Models. 3rd ed. SAS Institute Inc., Cary, NC.

Luger, D., D. Shinder, V. Rzepakovsky, M. Rusal, and S. Yahay. 2001. Association between weight gain, blood parameters, and thyroid hormones and the development of ascites syndrome in broiler chickens. Poult. Sci. 80:965–971.

McGovern, R. H., J. J. R. Feddes, F. E. Robinson, and J. A. Hanson. 1999. Growth performance, carcass characteristics, and the incidence of ascites in broilers in response to feed restriction and litter oiling. Poult. Sci. 78:522–528.

McGovern, R. H., J. J. R. Feddes, F. E. Robinson, and J. A. Hanson. 2000. Growth, carcass characteristics, and incidence of ascites in broilers exposed to environmental fluctuations and oiled litter. Poult. Sci. 79:324–330.

Mollison, B., W. Guenter, and B. R. Boycott. 1984. Abdominal fat deposition and sudden death syndrome in broilers: the effects of restricted intake, early life calorie (fat) restriction, and calorie:protein ratio. Poult. Sci. 63:1190–1200.

Newcombe, M. A., A. L. Cartwright, J. M. Harter-Dennis, and J. P. McMurtry. 1992. The effect of increasing photoperiod and food restriction in sexed broiler-type bird. II. Plasma thyroxine, triiodothyronine, insuline-like growth factor-I and insulin. Br. Poult. Sci. 33:427–436.

Noy, Y., and D. Sklan. 2002. Nutrient use in chicks during the first week posthatch. Poult. Sci. 81:391–399.

Plavnik, I., and S. Hurwitz. 1988. Early feed restriction in chicks: effect of age, duration, and sex. Poult. Sci. 67:384–390.

Robinson, F. E., H. L. Classen, J. A. Hanson, and D. K. Onderka. 1992. Growth performance, feed efficiency and the incidence of skeletal and metabolic disease in full-fed and feed restricted broiler and roaster chickens. J. Appl. Poult. Res. 1:33–41.

Romero L., M. L., M. E. Suárez O., J. G. Herrera H., A. Pro M., M. T. Sánchez-Torres E., and J. M. González A. 1999. Concentración de tiroxina (T_4) y triyodotironina (T_3) en pollos de engorda con restricción alimenticia y adición de energía y broncodilatador para el control del síndrome ascítico. Pages 270–272 in Memoria de la XXVII Reunión de la Asociación Mexicana de Producción Animal/9na. Reunión Internacional sobre producción de Carne y Leche en Climas Cálidos, Mexicali, Baja, CA.

Ruiz-Feria, C. A., M. T. Kidd, and R. F. Wideman, Jr. 2001. Plasma levels or arginine, ornithine, and urea and growth performance of broilers fed supplemental L-arginine during cool temperature exposure. Poult. Sci. 80:358–369.

SAS Institute. 1994. SAS/STAT User's Guide. Release 6.08 ed. SAS Instituite Inc., Cary, NC.

Steel, R. G. D., and J. H. Torrie. 1980. Principles and Procedures of Statistics. A Biometrical Approach. 2nd ed. McGraw-Hill, New York.

Suárez O., M. E., and M. Rubio R. 1989. Uso de restricción alimenticia como control parcial del síndrome ascítico. Vet. Méx. 20:193–195.

Sullivan, T. W. 1994. Skeletal problems in poultry: estimated annual cost and descriptions. Poult. Sci. 73:879–882.

Wideman, Jr. R. F., Y. K. Kirby, M. Ismail, W. G. Bottje, R. W. Moore, and R. C. Vardeman. 1995. Supplemental L-arginine attenuates pulmonary hipertension syndrome (ascites) in broilers. Poult. Sci. 74:323–330.

Yu, M. W., and F. E. Robinson. 1992. The application of short-term feed restriction to broiler chicken production: a review. J. Appl. Poult. Res. 1:147–153.

Zubair, A. K., and S. Leeson. 1994. Effect of varying period of early nutrient restriction on growth compensation and carcass characteristics of male broilers. Poult. Sci. 73:129–136.