HIGH CALCIUM INTAKE IN CHICKENS

M.W. McDONALD* and T. SHAFEY**

SUMMARY

The effect of supplying the young chicken with calcium in excess of its requirements has been examined in some detail. Excess calcium has been shown to reduce growth rate and increase feed conversion ratio, but the effect is inconsistent. Genetic effects on the response have been identified. The reduction in growth is considered not to result from altered calcium-phosphorus ratios as both calcium carbonates and phosphates depress growth. Increasing the electrolytes, sodium and potassium, does not effect the response to excess' calcium. Biotin addition reduces the effect on feed conversion ratio.

High calcium intake has been shown not to influence metabolizable energy or nitrogen retention but reduces nitrogen utilization and increases the faecal excretion of fatty acids as soaps. Chickens fed high calcium diets deposit fats with a lower palmitic and stearic acid and higher linoleic acid content.

INTRODUCTION

Recommended minimum calcium intake of chickens is 0.9 to 1.0% of the diet (ARC and NRC). O'Dell (1960), McDonald and Sol vyns (1963), Sathe and McClymont (1965a,b), Kondos and McClymont (1967), Bryden and Balnave(1983) and Johnson and Karunajeewa (1984) all found that calcium intake in excess of 1.2% of the diet depressed growth, Connor and Neil 1 (1971), Rogler and Parker (1972) and Karuna jeewa (1977) observed no depressi on with 1.6, 1.67 and 1.45% calcium respectively. Commercial practice in some parts of Australia and New Zealand is to allow the maximum calcium level of broiler diets to rise to as high as 1.6 to 1.8%, indicating that any reduction in performance that might occur in this range is of little economic significance.

High calcium intake has been associated with excessive deami nati on of amino acids (Kondos and McClymont, 1967), kidney damage (Cortina and San Gabriel, 1972), increased i nci dence of leg abnormal i ties (Oqura, 1981) and reduced availability of biotin (Bryden and Balnave, 1983).

This investigation aimed at identifying reasons for the differences in results obtained by different investigations and to develop methods for overcoming any physiological problems resulting from feeding high calcium diets.

---

* Dept. of Animal Husbandry, Q. A. C., Lanes, Q. 4343
** Dept. of Animal Husbandry, Faculty of Agriculture, University of Queensl and, St. Lucia 4067

EXPERIMENTS

The experiments described in this report were carried out on meat-type chickens, housed in single chick cages in a controlled environment. Chickens were usually fed a commercial broiler starter from hatching to about 6 days, then fed the experimental diets for 11-12days. Only a brief description of each eseriment is supplied.

1. Variation in response

It is clear from repeated experiments that excess calcium in the diet does not produce a consistant growth depression. This can be seen by the comparison of growth depressions observed by McDonald and Solvyns, and more recently by Plaisted (1983). In the first report, dietary calcium ranging from 0.9 to 2.5% was fed and weight gains declined significantly above 1.3%. Plaisted fed levels of calcium ranging from 0.8 to 2.2% to broiler chickens. She observed no consistant trend although weight gain at 1.2% calcium was significantly ($p<0.05$) higher than at 1.8%. Results reported by McDonald and Solvyns (1963) and Plaisted (1983) are contrasted in table 1.

Factors that have been examined to esplain this difference are particle size of added limestone, intestinal flora and different antibiotics, electrolyte balance in the diet and calcium phosphorus balance. The genotype of the chicken has been identified as possibly contributing to the differences between experiment results.

TABLE 1 Comparison of results of two experiments examining the effect of added calcium on growth rate of chickens.

a. McDonald and Solvyns (1964)

Calcium level %	Weight gain g in 6 days	
0.9	77.0	
1.1	77.5	
1.3	76.0	
1.7	70.8	
2.5	63.5	l.s.d (p=0.05) 4.0

b. Plaisted (1983)

Calcium level %	Weight gain g in 10 days	F.C.R.*
0.8	198	1.70
1.0	196	1.76
1.2	213	1.66
1.4	203	1.75
1.6	209	1.73
1.8	191	1.83
2.0	197	1.82
2.2	205	1.81
S.E. of mean	6.4	0.055

* F.C.R. Feed Conversion Ratio - g feed eaten/g weight gain.

2. Effect of calcium phosphorus balance

McDonald and Solvyns (1963) found no difference between the effect of calcium, when the calcium was supplied as calcium carbonate or tri-calcium phosphate, suggesting that excess calcium was not depressing weight gain through changing the calcium phosphorus ratio (Table 2)

TABLE 2 Comparison of calcium carbonate and tricalcium phosphate

Treatment	Weight gain g in 6 days	F.C.R.
Control	62.7	2.11
Added Ca (2.5%)	50.4	2.37
Added Ca+P	49.4	2.45
L.s.d (p=0.05)	5.0	0.12

We have repeated this experiment, using di calcium phosphate as a source of phosphate (Table 3).

In the earlier experiment, both calcium carbonate and calcium phosphate depressed growth and increased F.C.R. so it is unlikely that the growth depression produced by the carbonate was due to upsetting the calcium phosphorus balance. In the second series of experiments, changing the calcium phosphorus ratio by adding calcium carbonate failed to produce a significant depression of growth or to increase F.C.R. in one experiment, but did so in the second. In the experiment in which calcium depressed performance, dicalcium phosphate produced a significantly greater depression than the carbonate. In the experiment in which calcium carbonate failed to depress growth rate, dicalcium phosphate also failed to do so.

TABLE 3 Comparison of the effect of escess calcium, supplied as calcium carbonate or dicalcium phosphate, on chick: growth and F.C.R.

Exp1	Treatment	Weight gain g in 11 days	F.C.R.
	Control	222	2.04
	Calcium Carbonate*	213	2.05
	Dicalcium Phosphate*	210	2.09
	S.E. of mean	7.2	0.07
Exp2	Control	273	1.863
	Calcium Carbonate**	259	1.943
	Dicalcium Phosphate**	225	2.063
	L.s.d. (p=0.05)	14	0.065

* 1.2% Ca added.
** 1.0% Ca added.

3. Interaction with other minerals

The original observations on high calcium intake were made in experiments in which different meatmeals were compared. Diets

containing high levels of meatmeal also tend to contain high sodium levels. McDonald and Solvyns (1964) found no difference in the effect of high calcium, either as carbonate or phosphate, in diets with or without 0.4% added sodium (Table 4).

TABLE 4 Effect of sodium on the response in weight gain to excess calcium, g in 6 days.

Calcium added	Low Sodium	High Sodium
Nil	60.5	64.9
Ca CO3	48.4	52.4
Ca3(PO4)2	46.1	52.7
L.s.d (p=0.05) 7.1 g		

This experiment has been repeated in the present series (Table 5).

Table 5 Effect of Sodium on the Response in Weight Gain to Excess Calcium, g in 12 days.

Calcium added	Low Sodium	High Sodium
Nil	272.4	273.0
CaCO3	260.7	257.4
CaHPO4	228.3	222.6
L.s.d. (p=0.05) 19.4 g		

The substitution of vegetable protein concentrates for meatmeal has raised the potassium content of chicken diets. This suggested that the lack of depression in some commercial diets might be related to the higher potassium intake. This was not supported by experimental results (Table 6). Increased calcium intake was found to significantly ($p<0.05$) reduce weight gain and increase F.C.R., both in the presence or absence of added potassium carbonate (0.56% K).

These results have been examined after the technique of Monjin (1980) but analysis of electrolyte balance does not help in understanding the absence of an effect of sodium or potassium on the depression, or the variation in response from one experiment to another.

TABLE 6 Effect of potassium on the response to excess calcium, period 12 days.

Treatment	Weight gain g	F.C.R.
Low K, low Ca	292.1	1.69
Low K, high Ca	261.0	1.83
High K, low Ca	280.9	1.75
High K, high Ca	252.4	1.87
L.s.d (p=0.05)	18.5	0.11

4. Effect of biotin

Bryden and Balnave (1983) found that **high calcium intake in broilers** reduced the **level** of **plasma biotin, as well as reducing** growth rate. **Possible** effect **of biotin supplementation** on the growth **depression** due **to high calcium intake,** has been **examined in two experiments.**

In the first experiment, wheat and sorghum were compared because of the **lower availability of biotin in wheat (Whitehead, et al , 1982). High calcium intake increased** F.C.R. but **did** not affect **weight gain. Biotin** supplementation **imcreased weight gain** and reduced F.C.R. **in** the wheat based diets, but not **in** the sorghum based **diet. High calcium intake** increased F.C.R. **in** the absence of **biotin supplementation,** but not **in its** presence. **Grain type by calcium supplementation interactions were** not **significant.**

TABLE 7 Effect of **biotin** on growth depression due **to high calcium intake.**

Grain	Biotin@	Weight Gain g in 12 days	F.C.R.
Wheat	nil	284.4	1.737
	+	304.0 *	1.679 *
Sorghum	nil	303.8	1.660
	+	300.4	1.680
Calcium	Biotin@		
Nil	nil	297.6	1.666
	+	300.6	1.671
+	nil	290.3	1.732
	+	303.7 #	1.688 *
L.s.d. (p=0.05)		16.2	0.043

# p<0.10 * p<0.05
@ Biotin added at 0.2 g/tonne.

In the second **experiment, biotin** was added to diets to which **calcium** was added as carbonate or phosphate **(Table 8).** Added **calcium** carbonate produced a non-significant **depression in** growth. **Di-calcium** phosphate **additi** on produced a **signi f i cant** reduction **in** growth and **increase in** F.C.R.. **Addition** of **biatin did** not effect **weight gain but did** prevent the **increase in** F.C.R. when **dicalcium** phosphate was added.

TABLE 8 Effect of biotin on response to calcium as carbonate and dicalcium phosphate.

Treatment	Biotin@	Weight Gain g in 12 days	F.C.R.
Control	---	312.5	1.757
Carbonate	---	292.7	1.797
Phosphate	---	254.2*	1.979*
Control	added	316.4	1.794
Carbonate	added	310.0	1.833
Phosphate	added	252.8*	1.806
L.s.d.	(p=0.05)	25.7	0.102

@ Biotin added at 0.2 g/tonne

5. **Genetic effects**

To **assess** the **possibility** that genotype **nutrition interactions** may account for the **inconsistant** responses, four **strain5** of **chickens selected** for growth rate and fat **depasition** by Pym(1980), were compared. The **strains were:**

C **control**
W **selected** for **high 8 week weight.**
L **selected** for **low abdominal** fat.
F **selected** for **high abdominal** fat.

Each **strain was fed diets containing 1.0%** or 2.0% **calcium. High calcium intake significantly** reduced **weight gain and increased** F.C.R.. **When strains** were **examined individually, strain** L demonstrated no effect. strains W and C showed **non-significant** depression of growth rate and **increase in F.C.R., while strain** F demonstrated a **significant** growth reduction and **increase in** F.C.R. **(Table 9).**

TABLE **9** Comparison of growth and feed **conversion** responses of four **strains** of **chicken to increased calcium** intake.

Strain	Diet	Weight Gain g in 12 days	F.C.R.	Plasma Calcium Total mE/100ml	Ionised mE/100ml	PO4 Total
W	Control	223.7	1.66	2.6	1.645	2.57
	Ca added	217.6	1.75	3.09***	1.65	1.82***
L	Control	203.8	1.82	2.42	1.68	2.35
	Ca added	200.0	1.81	2.89**	1.70	1.60***
F	Control	225.2	1.62	2.79	1.65	2.28
	Ca added	200.1*	1.78*	3.11*	1.80***	1.89
C	Control	209.2	1.62	2.59	1.68	2.67
	Ca added	191.4	1.73	3.15***	1.69	1.61***
L.s.d. (p<0.05)		20.4	0.13	0.365	0.10	0.43

* p<0.05 ** p<0.01 **p<0.001

Plasma electrolytes were analysed. Strain F differed from the other three strains in demonstrating a lower rise in plasma total calcium but a higher rise in ionised calcium than the other strains, when the high calcium diet was fed. All strains showed a reduction in plasma phosphate, when the high calcium diet was fed, but in strain F this reduction was not significant ($p>0.05$).

6. Effect of high calcium on retention of fats and protein

In rats, high calcium intake reduces the retention of nitrogen and increases the excretion of fatty acids (Goto and Sugai, 1975). Part of the effect of calcium an fat absorption is possibly due to the formation of relatively insoluble calcium soaps from dietary fatty acids.

The effect of calcium intake on apparent metabolizable energy (A.M.E.), faecal calcium soap and nitrogen utilization were measured. N. utilization was calculated as the percentage of ingested N. absorbed from the alimentary canal. N. retention was calculated as the percentage of ingested N. retained in new tissue. Results are summarised in table 10.

Increasing calcium intake, either by adding carbonate or monohydrogen phosphate, did not influence the A.M.E. of the basal diet. The high calcium intake significantly depressed the nitrogen utilization but not the nitrogen retention. Connor and Neill (1971) also found that increased calcium intake did not effect observed M.E. values of the diet or nitrogen retention. Overall digestability of fatty acids was not significantly reduced but there was a significant increase in the amount of fatty acids excreted as soaps.

TABLE 10. Effect of excess calcium intake on A.M.E., nitrogen utilization and faecal soaps.

Treatment	A.M.E. kJ/g	N. Utilization %	N. Retention. %	Neutral Faecal Fats %	Faecal Soaps %
Control	11.9	90.5	17.0	7.6	1.3
CaCO3	12.3	89.2**	17.8	6.4	2.4**
CaHPO4	12.0	88.7**	17.5	7.4	2.2*
S.E.	0.17	--	0.34	0.50	--
L.s.d. (p=0.05)	--	0.8	--	--	0.8

Analysis of the composition of carcass fat showed that there was a reduction in the amount of palmitic (16:0) and stearic (18:0) acids in the tissue lipids. This was off set by an increase in linoleic acid (18:2). This suggests that the increase in faecal soaps was largely due to the formation of calcium palmitate and stearate. If fats are lost in this way, when high calcium diets are fed, it is surprising that an effect on M.E. was not observed.

The reduction in nitrogen utilization may have resulted from a change in the intestinal pH, from 3.91 to 6.18 in a similar experiment. However nitrogen retention did not reflect the decrease in utilization when excess calcium was fed. A possible explanation might follow from the observation that the duodenum wall was 26% thinner when excess calcium was fed, than when a normal diet was ingested.

CONCLUSIONS

The results presented suggest that it is not clear how high calcium intake depresses chicken growth rate or increases feed conversion ratio. There are some indications that the ultimate effect is to depress feed intake (e.g. Saville, 1968). This might serve to esplain genetic effects as strains of birds differ in the strength of the processes controlling feed intake and selection for growth rate may result in increasing appetite of the birds (Lin, 1981).

That excess calcium affects nitrogen metabolism was reported by Kondos and McClymont and confirmed in this study. We are now looking at effects on the availability of specific amino acids. The interaction with biotin may idicate a specific effect, but is more likely a general effect on availability of a range of vitamins, again as suggested by some of Sathe and McClymont's and Kondos and McClymont's data. The significance of the effect on fat utilization needs further study.

ACKNOWLEDGEMENTS

Dr A.C. Kondos is thanked for for analytical advice. Dr. A. Clague: Pathology Department, Royal Brisbane Hospital provided facilities and assisted with plasma electrolyte analyses. Mr. F. Gorbacz assisted with the management of the chicks. Inghams and White Wings have been generous with chickens; Dr. R. Pym, University of Queensl and supplied the specially selected chickens. The research was partially funded by the Chicken Meat Research Fund.

REFERENCES

BRYDEN, W.L. and BALNAVE, D. (1983) Proc. W.P.S.A. Far East and Sth. Pacific Feed., Adelaide p. 104

CONNOR, J.K. and NEILL, A.R. (1971) Aust. J. Exp. Agric. Anim. Husb., 11:383

CORTINA, M.M. and SAN GABRIEL A. (1972) C.A.B. abstr. 405939

GOTO, S. and SUGAI, T. (1975) Nutr. Reports Int. 11.1:49

JOHNSON, R. J. and KARUNAJEEWA H. (1984) Proc. Poultry Husb. Research Foundation Symposium 1984, Sydney

KARUNAJEEWA, H. (1977) Aust. J. Exp. Agric. Anim. Husb. 17: 944

KONDOS, A.C. and McCLYMONT G.L. (1967) Proc. 1967 Poultry Science Conv., Surfers Paradise p.95

LIN, C.Y. (1981) W.P.S.A. J. 37:106

McDONALD, M. W. and SOLVYNS A. (1964) Proc. 1964 Poultry Science Conv., Surfers Paradise p.112

MONGIN, F. (1980) Proc. 1980 Sth. Pacific Poul. Sci. Conv. p.364

O'DELL, B.L. (1960) Fed. Proc. 19:648

OGURA, Y. (1981) Nat. Inst. Anim. Health Quarterly 21 (3): 141

PLAISTED, ROSEMARY J. (1983) Thesis for B.App. Sci. (Rural Tech.), Q.A.C., Lawes, Q

ROGLER, J.C. and PARKER, H.E. (1972) J. Nutr. 102:1699

SATHE, B. S. and McCLYMONT (1965 a) Aust. J. Agric. Res. 16:243

--- and --- (1965 b) Aust. J. Agric. Res. 16:491

SAVILLE, D.G. (1968) Proc. Aust. Soc. Anim. Prod. 6:418

WHITEHEAD, C.C., ARMSTRONG J.A. and WADDINGTON D. (1982) Brit. J. Nutr. 48:81