ADVANCES IN REDUCING BODY FAT IN BROILERS BY NUTRITIONAL AND CHEMICAL MEANS

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SUMMARY

Increased body fat in broiler chickens and consumer resistance to high dietary fat levels has led to the need to develop methods to reduce the deposition of fat in the chicken. Feed restrictions and chemical feed additives may offer the most-practical short-term solutions and these strategies were examined in a series of experiments.

Feed restrictions by quantitative feeding, based on the energy content of the diet and the birds bodyweight, as well as dietary dilution were examined when applied to broilers aged from 7 to 28 days. The consequences of these restrictions on the metabolism and the rate of fat deposition are discussed. Finisher-feeds treated with chemical additives, when fed to broilers from 25 days of age, were also tested.

The most dramatic effects were obtained when feed restrictions were applied to 7 day old broilers. Dietary dilutions decreased body fat but had detrimental effects on bodyweight. Iodinated casein added to the finisher feed decreased body fat with no effects on bodyweight. Theophylline and caffeine, however, depressed feed intake and consequently, growth rate..

INTRODUCTION

The production of chicken meat in Australia increased by 1432% between 1960 and 1987, when 337,100 tonnes were produced (Fairbrother 1987). The liveweight gain of broiler chickens has also increased rapidly over this period and with this increase in growth rate, there has frequently been a concomitant increase in body fat. Recently, however, consumer resistance to high levels of dietary fat has intensified and methods need to be established to counteract the increased levels of body fat in broiler chickens.

Many factors influence the level of fat in the chicken, such as the environment , genotype, age and sex of the bird, However , the nutrition of the bird appears to be the most critical factor in the rapid development of a program to counteract the increase in body fat.

Previous research has centred around the manipulation of the energy: protein ratio of the diet. Although reducing fat levels, bodyweight may be adversely affected or the cost of the diet too great to warrant commercial practise . Two methods that may be commercially successful are the use of restricted feeding practices and the addition to the diet of chemicals that promote lean tissue growth at the expense of fat deposition.

The use of feed restrictions is well known in the layer and broiler breeder industries. Their use in broiler production is relatively new. Research initiated in Israel (Plavnik and Huwitz 1985) indicated that feed restriction of young chickens reduced the body fat content of the bird while improving feed conversion efficiency, often with no influence on bodyweight. Their results proved to be inconsistent and full compensation of lost bodyweight was not often achieved.

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Work in Australia by Jones and Farrell (1987, 1988) examined a range of feed restrictions, ranging from 7-50% *ad libitum* and for durations of 1-10 days. When imposed on 7 day old birds, restrictions of less than 4 days had no effect on body fat at slaughter. If the duration was too long, fat was reduced but bodyweight failed to recover completely. The optimum restriction, 20% *ad lib.* for 4 days, produced consistent results over a range of broiler strains: It reduced body fat, maintained bodyweight and generally improved feed conversion efficiency..

The use of chemicals in reducing body fat has also been studied only recently. Iodinated casein has been shown to reduce fat levels in the chicken, but at high levels of incorporation it has deleterious effects on carcass composition and dressed weight (Wilson *et al* 1983). The repartitioning agents or beta-adrenergic agonists have been examined in lambs (Baker *et al* 1984), steers (Ricks *et al* 1984) and pigs (Jones *et al* 1985) and have reduced carcass fat levels. The repartitioning agents decrease protein degradation (Li and Jefferson 1977), stimulate lipolysis (Ricks *et al* 1984) and appear to operate in conjunction with the growth hormone. Results obtained in broilers (Dalrymple *et al* 1984) are less pronounced and the effect of these chemicals in broilers may be sex, strain and dose dependent.

This paper examines the use of two strategies to reduce the level of body fat in broilers by nutritional means. Firstly feed restrictions are examined in conjunction with dietary dilution techniques to provide a practical feeding method for broilers, optimum feeding strategies are examined and the consequences of these strategies explored. Secondly, the use of thyroactive, beta-adrenergic and alkaloid chemicals, when incorporated in the finisher diet of the broiler, is also examined.

MATERIALS AND METHODS

Feed restriction experiments

One-day-old unsexed (Experiments 1 and 2) or female (Experiment 3) broiler chicks of a commercial strain were placed in electrically heated brooders until 6 days of age. They were then individually weighed, wing-tagged and allocated to groups of 8 (Expt. 1 and 2) or 10 (Expt. 3) in small wire-mesh cages, At 14 days, they were transferred to larger cages, where they were kept until slaughter. Birds were fed a commercial broiler starter crumble to 28d and then a commercial finisher feed. The experiments were conducted in environmentally controlled rooms maintained at 32^{o}C, with gradual reductions in temperature to 20^{o}C by 28 days of age. Continuous lighting was provided. The birds were weighed and fed daily during the restriction phases and at weekly intervals otherwise. Prior to slaughter, the birds were starved for 12h. After slaughter by cervical dislocation, the abdominal fat pad was removed and weighed, Birds used for carcass analysis were frozen in polythene bags at -20^{o}C, cut into small pieces by a bandsaw and finely ground twice with an electrically-powered mincer. Moisture was determined by drying in a force draught oven at 70^{o}C for 5d. Protein was determined using a Kjeldahl technique with a selenium catalyst (A.O.A.C. 1984) and distillation by the method of Ivan *et al* (1974). Fat was analysed by measuring the density of a fat-tetrachloroethylene extract (Usher *et al* 1973) and ash determined by combustion at 600^{o}C for 4h in a muffle furness.

Experiment 1 used a factorial, randomised block design with 5 treatments and 3 replicates. Treatments were imposed on chicks at 7 days of age using two methods of feed restriction. The treatments were - *ad libitum* control, feed restriction based on bodyweight (i.e. 3.1kJ/g $W^{0.67}$/d, Jones and Farrell 1987) for 4 days and 3 restrictions using dietary dilution techniques. These treatments used diets containing 35%:65%; 40%:60% or 45%:55% starter mash: rice hulls for 4, 5 or 6 days duration respectively. After restriction birds were fed ad libitum until slaughter at 49 days of age. The treatments were equivalent to 20% (3.1 kJ/g $W^{0.67}$/d; 35%:65% starter mash: rice hulls), 25% (40%:60%) or 30% (45%:55%) ad libitum intake.

Experiment 2 was of a factorial, randomised block design incorporating 10 treatments and 3 replicates. The experiment was designed to examine the best restriction stragegy given that 3.1 kJ/g$W^{0.67}$/d represented the optimum restriction severity. The treatments were: ad libitum control, feed restriction beginning at 7, 21 or 28 days of age for 4 days continuously, 2 periods of 2 days with 2 days re-alimentation between restrictions, or 3 periods of 12h starvation followed by 24h restriction with 36h realimentation between restriction periods. Birds were fed ad libitum before and after restriction and slaughtered at 49 days of age.

Three treatments were imposed in Experiment 3 using a factorial, randomised block design with 4 replicates. The treatments were - ad libitum control, or feed restriction (3.1kJ/g$W^{0.67}$/d) for 4 or 6 days commencing at 7 days of age. Birds were fed ad libitum after restriction until slaughter at 70 days of age. Total body water and body fat were estimated throughout the experiment using tritiated water techniques (Johnson and Farrell, 1988).

Chemical additive experiments

Experimental lines of broilers obtained from Dr. R.A.E. Pym, University of Queensland and commercial broiler chickens were housed and maintained as in the feed restriction experiments. Unsexed experimental broiler chicks were used in Experiment 4 and commercial male broiler chicks in Experiments 5, 6 and 7. Birds were allocated to groups of 6 (Experiments 4, 5) or 7 (Experiments 6, 7). They were fed a commercial starter crumble diet until 25 days of age (Experiment 4) or 28 days of age (Experiments 5, 6 and 7) whereupon they were transferred to a commercial finisher mash with the various chemical treatments thoroughly incorporated.

Experiment 4 examined the influence of the beta-agonist cimaterol (5-(1-hydroxy-2-(isopropylamine)ethyl)anthranilonitile) on the amount of body fat. The experiment was a randomised block design with 4 treatments and 3 replicates. The treatments were 0, 0.2, 0.4 and 0.6 mg/kg cimaterolmixed with the finisher feed. Birds were slaughtered at 56 days of age. The abdominal fat pad was removed and weighed. Fat analysis was conducted as previously described.

The influence of iodinated casein was examined in Experiment 5. The experiment used 3 treatments and 4 replicates in a randomised block design. The 3 treatments were 0, 50 and 100 mg/kg iodinated casein in the finisher feed. Birds were slaughtered at 49 days and abdominal fat pads removed and weighed.

Experiment 6 used 3 treatments and 3 replicates in a randomised block design. The 3 treatments were 0, 500 and 1000 mg/kg theophylline added to the finisher feed. Birds were slaughtered at 49 days and the abdominal fat pad removed and weighed.

Experiment 7 considered the influence of caffeine. Four treatments and 4 replicates were used in a randomised block design. The treatments were 0, 500 and 1000 mg/kg caffeine added to the finisher feed and a control (0 mg/kg caffeine) pair-fed to the 1000 mg/kg group. Birds were slaughtered at 49 days and the abdominal fat pad removed and weighed.

Respiration calorimetry experiments

Respiration calorimetry experiments were designed to examine the metabolic consequences of both feed restrictions and chemical additives on female commercial broiler chickens, The calorimetry procedures used were those described by Farrell (1972) and Pym and Farrell (1977). In the feed restriction experiment, the birds were fed either *ad libitum* or restricted fed to 3.1 $kJ/gW^{0.67}/d$ for 4 days. Measurements were made prior to, during, and twice after the feed restrictions were imposed. Restricted feeding commenced at 7 days of age,

The inclusion of theophylline, iodinated casein or cimaterol in the finisher feed was examined in the second experiment. The levels of inclusion were 500 mg/kg, 50 mg/kg and 0.5 mg/kg respectively. The birds were fed untreated finisher mash for 3 days and were then transferred at 24 days of age to the treated feed. Measurements were then taken over a 3 day period. Due to the poor palatability of theophylline, the birds on the other treatments were pair-fed to the theophylline treatment.

RESULTS

A dietary diluent (rice hulls) allows the energy restriction to be applied commercially. The influence of a range of dietary dilutions on the growth performance and body fat of broilers is shown in Table 1 and are compared to a previously successful restriction ie 3.1 $kJ/g W^{0.67}/d$ (20% *ad libitum*).

Table 1. The influence of feed restriction and dietary dilution on the performance of commercial broiler chickens (Experiment 1).

	ad lib.	20% *ad lib.*	Starter : rice hulls 35:65	Starter : rice hulls 40:60	Starter : rice hulls 45:55
Bodyweight @ 7d (g)	134a*	133a	133a	134a	132a
@ 49d (g)	2157a	2082ab	2024bc	2004bc	1971c
Weight gain (g)	2023a	1949ab	1891bc	1870bc	1839c
Intake (g)	4217a	4032b	3939b	4011b	3934b
FCR	2.08ab	2.07ab	2.08ab	2.00b	2.14a
Abdominal fat pad (%)	2.26a	2.02ab	1.84b	1.94b	2.02ab
Total body fat (%)	14.0a	12.4b	11.8c	12.1bc	12.4b

*In this and other tables values within rows followed by a common letter are not significantly different ($P<0.05$).

The quantitative restriction (20% *ad lib.*) for 4 days produced a 3% decrease in bodyweight at 49 days and a 4% decrease in feed intake. Feed conversion efficiency was not affected but total body fat was reduced by 11%. If considered on a fat-free body weight basis, the weight lost by the restricted birds was 32g non-fat tissue and 43g fat. The three dilution treatments reduced the size of the abdominal fat pad and decreased total body fat but had adverse effects on the growth performance of the birds. Supplementary work (data not presented) indicated that the rice hull diluted diets were less acceptable than expected hence imposing greater restrictions than intended.

The data obtained from Experiment 2 indicate that feed restrictions imposed at 7 days of age allow full recovery of body weight to be obtained whilst maximising fat loss. Restrictions imposed at 21 days of age allowed reccvery of bodyweight but tended to increase body fat (as represented by the abdominal fat pad) and decrease feed conversion efficiency, although in both cases not significantly ($P>0.05$).

Table 2. The influence of the time of feed restriction on the performance of commercial broiler chickens (Experiment 2).

	ad lib.	7 days			21 days		
		4d	2x2d	3x1.5d	4d	2x2d	3x1.5d
Bodyweight @ 7d (g)	124a	126a	126a	124a	130a	125a	119a
@ 49d (g)	1896bc	1891bc	1939a	1917ab	1928ab	1866c	1918ab
Weight gain (g)	1772a	1765a	1813a	1793a	1798a	1741a	1799a
Intake (g)	3555ab	3394b	3424b	3481b	3734a	3561ab	3556ab
FCR	2.01ab	1.92b	1.89b	1.94b	2.08a	2.05a	1.98ab
Abdominal fat pad (%)	0.84ab	0.66bc	0.56c	0.84ab	0.94ab	1.03a	0.90a

Restrict ions in-posed at 28 days (data not presented) did not allow full recovery of bodyweight and did not affect fat levels. The use of a non-continuous restriction whereby periods of re-alimentation are followed by further restrictions produced the best results, most noteably when the restrictions began at 7 days of age (Table 2).

The effects of successful feed restrictions are only transitory, but if too severe, permanent changes in body composition can be obtained. The third experiment was designed to examine the effect of feed restriction on birds grown beyond normal slaughter weight. The data (Table 3) indicated that, at 70 days, the carcass composition of feed restricted birds was similar to that of ad libitum fed birds.

Table 3. The influence of feed restrictions on the carcass composition of commercial female broiler chickens at 70 days of age (Experiment 3).

	ad lib.	20% ad lib.	
		4d	6d
Moisture (g/kg)	604a	590b	602ab
Protein (g/kg)	154a	154a	157a
Ash (g/kg)	37a	34a	35a
Abdominal fat pad (g/kg)	39ab	42a	34b
Total body fat (g/kg)	231a	247a	220a

The experiment followed the course of fat deposition in the birds using tritiated water techniques to estimate body water and then to calculate body fat by correlative procedures. The development of body fat can be described by the use of allometric equations (shown below) which indicate that the development of body fat is delayed by feed restriction, but as shown in Table 3, eventually reaches parity with that of ad libitum fed birds.

<u>Ad libitum</u>		log fat = -1.21 + 1.20 log bodyweight R^2, = 0.98
Restriction for	4d	log fat = -1.34 + 1.24 log bodyweight R^2, = 0.98
"	6d	log fat = -1.41 + 1.27 log bodyweight R^2, = 0.98

Increasing the level of cimaterol in the finisher feed had little effect on bodyweight or feed intake, with slight, non-significant depressions as the level of cimaterol increased. The size of the abdominal fat pad was decreased by 12%, 19% and 6% by the 0.2, 0.4 and 0.6 mg/kg cimaterol treatments, respectively but only at 0.4mg/kg cimaterol was it significantly ($P<0.05$) lower than the controls.

Table 4. The effect of cimaterol in the finisher feed on the performance of experimental broiler chickens (Experiment 4).

	Cimaterol (mg/kg) 0	0.2	0.4	0.6
Bodyweight @ 25 d (g)	428 ab	426 ab	412 b	434 a
@ 56 d (g)	1418 a	1377 a	1367 a	1367 a
Weight gain (g)	991 a	951 ab	947 ab	933 b
Intake (g)	2614 a	2573 a	2532 a	2514 a
FCR	2.64 a	2.71 a	2.68 a	2.70 a
Abdominal fat pad (%)	2.29 a	2.02 ab	1.85 b	2.15 ab
Total body fat (%)	14.59	11.98	13.09	13.83

Table 5. The effect of iodinated casein in the finisher feed on the performance of commercial male broiler chickens (Experiment 5).

	Iodinated casein (mg/kg) 0	50	100
Bodyweight @ 28d (g)	724 b	725 ab	727 a
@ 48d (g)	1855 a	1908 a	1862 a
Weight gain (g)	1133 a	1183 a	1134 a
Intake (g)	2594 a	2362 b	2338 b
FCR	2.29 a	2.00 b	2.06 b
Abdominal Fat pad (%)	1.16 a	0.71 b	0.79 b

The inclusion of iodinated casein in the finisher diet markedly decreased the size of the abdominal fat pad (Table 5). The two rates used, 50 and 100 mg/kg, decrease the size of the fat pad by 39% and 32% respectively. Bodyweight at slaughter was not affected but feed intake was depressed by 9% and 10% respectively. The depression in feed intake whilst bodyweight was maintained was reflected in improved feed conversion (Table 5) and indicated that the addition of iodinated casein to the finisher diet depressed fat deposition and improved non-fat accretion. No improvement in performance was obtained when the level of iodinated casein was doubled (100 mg/kg).

The two alkaloid chemicals, theophylline and caffeine both had adverse effects on the growth performance of the birds. Although they reduced the size of the abdominal fat pad, this is an artefact of the depressed feed intakes and hence bodyweights (Table 6 and 7). In common with most alkaloid chemicals, theophylline and caffeine are bitter to the taste and hence acceptability of the diets was depressed.

Table 6. The effect of theophyiline in the finisher feed on the performance of commercial male broiler chickens (Experiment 6).

	Theophylline (mg/kg) 0	500	1000
Bodyweight @ 28d (g)	758 a	760 a	758 a
@ 48d (g)	1717 a	1587 b	1379 c
Weight gain (g)	958 a	826 b	621 c
Intake (g)	2405 a	2076 b	1717 c
FCR	2.51 b	2.51 b	2.76 a
Abdominal fat pad (%)	2.81 a	2.45 a	1.76 b

Table 7. The effect of caffeine in the finisher feed on the performance of commercial male broiler chickens (Experiment 7).

	Caffeine (mg/kg) 0	500	1000	Pair-fed*
Bodyweight @ 28d (g)	718 a	719 a	719 a	721 a
@ 48d (g)	1876 a	1771 a	1622 b	1421 c
Weight gain (g)	1163 a	1052 b	903 c	700 d
Intake (g)	2414 a	2189 b	1867 c	1845 c
FCR	2.10 b	2.09 b	2.07 b	2.65 a
Abdominal fat pad (%)	0.88 a	0.79 a	0.30 b	0.87 a

*Birds pair-fed to level of intake of 1000 mg/kg caffeine treatment

Theophylline at 1000 mg/kg depressed the size of the abdominal fat pad by 37% , but depressed bodyweight by 35% and feed intake by 29%. The effects at 500 mg/kg inclusion level was similar but less dramatic (Table 6). The incorporation of caffeine showed similar effects (Table 7). In this final experiment a group receiving a caffeine-free diet were pair-fed to birds receiving the 1000 mg/kg caffeine diet (Table 7). The pair-fed group had 22% lower bodyweight , similar feed intake, a poorer feed conversion ratio and a larger abdominal fat pad indicating that a caffeine addition to the diet improved growth performance and decreased fat levels but due to poor palatability these effects were masked.

Respiration calorimetry indicated that the effects of feed restriction at 7 days were still apparent at 30 days of age (Table 8) . During the restriction phase (7-10 days) the metabolisability of the diet and feed intake were depressed with subsequent effects on the energy of nitrogen balance of the birds. Some of these effects were maintained immediately after the restriction was lifted, however , only heat production and energy retention were affected at 30 days of age. Heat production was higher in restricted-fed birds (Table 8) and consequently, energy retention was depressed. The maintenance energy requirement of the birds was reduced by 60% due to feed restriction (803 kJ/kg$^{0.75}$). No effects on the nitrogen economy of the bird were observed.

The use of chemical additives produced no consistent effects on the metabolism of broiler chickens measured by respiration calorimetry (Table 9).

Table 8. The influence of feed restriction ($3.1 kJ/gW^{0.67}d$: 4 days) on the energy and nitrogen balances of female commercial broiler chicks

Days		Pre-restriction 4-6	Restriction 7-10	Post-restriction 11-13	30-32
Metabolisability	C	75.8	75.4	75.1	74.3
(%)	R	74.0	67.3***	74.2	73.0
Feed intake	C	498	767	847	593
(g)	R	494	174***	848	561
ME intake	C	2478	2377	2263	1468
($kJ/kgW^{0.75}d$)	R	2462	540***	2926***	1539
Heat production	C	1188	1183	1223	839
($kJ/kgW^{0.75}d$)	R	1178	851**	1291**	908*
Energy	C	40.4	35.5	34.5	33.7
retention (%)	R	39.9	-42.2***	42.5**	30.1**
N intake	C	6.78	6.46	6.13	3.96
($g/kgW^{0.75}d$)	R	6.76	1.63**	8.02**	4.38
N retention	C	57.7	55.3	51.3	47.8
(%)	R	57.5	38.2**	50.8	46.0

C = ad libitum fed; R = restricted fed *P<0.05; ** P<0.01; ***P<0.001.

Table 9. The effect of added theophylline, iodinated casein or cimaterol in the finisher feed on 24 day old female commercial broilers

	Control	Theophylline	Casein	Cimaterol
Metabolisability (%)	73.2 a	72.0 ab	72.4 a	71.0 b
Feed intake (g)	518 ab	505 b	523 a	525 a
ME intake ($kJ/kgW^{0.75}d$)	1248 a	1154 b	1218 a	1265 a
Heat production ($kJ/kgW^{0.75}d$)	893 ab	855 b	928 a	914 a
E retention (%)	27.7 a	25.1 a	22.5 a	27.3 a
N intake ($g/kgW^{0.75}d$)	3.00 b	2.86 c	3.01 b	3.16 a
N retention (%)	50.0 a	46.0 b	52.0 a	51.6 a

Cimaterol reduced slightly the metabolisability of the diet whereas iodinated casein and theophyliine had no effect. ME intake and heat production of birds fed theophylline were reduced but corresponded to a depressed feed intake (Table 9). Energy retention was unaffected although nitrogen retention was depressed by theophylline.

DISCUSSION

Feed restrictions in broilers, designed to decrease body fat, have been investigated only recently. Various methods have been tested and have involved altering the energy:protein ratio of the diet, intermittent or meal feeding, limiting water access, changing the environmental temperature or the use of proportionate or quantitative feed restrictions.

Each strategy has shortcomings. Birds can readily adjust to intermittent or meal feeding programs and can increase their intake to 'normal' levels with a possible increase in body fat. Limited water access produces wet droppings (Ross 1960) and temperature regulation is costly. If the protein content of the diet is increased to high levels, additional costs may be incurred. Similarly, birds can adjust feed intake (if the change in ratio is slight> to meet energy or protein requirements (Rosebrough and Steele 1985). The use of quantitative feed restrictions, for short periods of time, seems to be the most successful means of reducing body fat whilst maintaining bodyweight.

The recovery from a period of undernutrition, induced by feed restrictions, is influenced by a number of factors (Wilson and Osburn 1960). The two most important of these are the severity and duration of the undernutrition, As these increase, the recuperative ability of the animal diminishes. If the restriction is too mild, overcompensation may arise (Clarke and Smith 1938) and fat levels will increase. If too severe, bone growth will be retarded (Brody 1945) and bodyweight will not recover fully.

The response to realimentation after a period of undernutrition can be summarised as follows: If the animal loses weight during undernutrition , bodyweight will not, or be slow to, recover and fat levels will be depressed. If bodyweight increases, the recovery will be complete and fat levels may rise. If bodyweight is maintained during undernutrition, then recovery will be generally complete and fat levels depressed.

The work of Plavnik and Hurwitz(1985) used feed restrictions based on the energy requirement for maintenance, so that birds would not gain weight over the restriction phase . When this level ($6.3kJ/gW^{0.67}.d$) was applied to Australian broiler strains (Jones and Farrell 1987) it was found to be twice the requirement for maintenance and which may explain the variability in the results obtained by Plavnik and Hurwitz (1985). The use of the $3.1kJ/gW^{0.67}d$ restriction has given more consistent results and is applicable over a range of broiler strains.

The experiments present.& here were designed to examine the use of feed restrictions that could be applied in commercial industry and to clarify some effects of feed restrictions on body composition and the recovery from the undernutrition imposed. One of the strains used was particularly lean yet favourable results were still obtained.

The use of rice hulls to dilute commercial diets has some potential although this potential was not fully realised in the experiment conducted. As previously mentioned, acceptability of the rice hulls produced more severe restrictions than intended and hence decreased final bodyweights. Fat levels were markedly depressed, but without full bodyweight recovery, the results are not satisfactory - especially when no premium is paid for lean birds. The 40:60 starter mash: rice hull diet, when applied for 4 days may produce better results ie decreased body fat while maintaining bodyweight.

Feed restrictions applied to birds at later ages (21 and 28 days) had either no effect or increased fat levels. The relative stage of maturity of the birds, and -especially the maturity of the body components, therefore, has a bearing on the success of the feed restrictions. The restrictions examined have been-applied to birds that were slaughtered at 49 days, regardless of bodyweight. If the birds were to be grown for shorter periods or to heavier bodyweights, then the restrictions would have to be modified to obtain the best results. The restriction used by Plavnik and Hurwitz (1985) when applied to turkeys grown to 168 days of age (Plavnik and Hurwitz 1988) were not successful. If the restriction was more severe or for a longer duration, then success may have been achieved. The application of two short periods of restriction at an early age appears to hold great promise both in reducing body fat as well as improving feed efficiency.

The metabolic consequences of feed restrictions and the delay in fat deposition are not clearly understood. However, feed restrictions have been shown to affect lipoprotein lipase activity (Pearce and Johnson 1984) and influence the levels of two enzymes involved in fatty acid synthesis (Calabotta et al 1985). The use of respiration calorimetry allows changes in the bird's metabolism to be observed. The use of feed restrictions alters the use and partitioning of the energy component of the diet. Heat production was increased in restricted-fed birds and consequently energy retention, as fat, was decreased. Again, the reasons for this change in energy use are not clearly understood,

The chemicals examined in the experiments presented here produce metabolic changes analogous to the changes produced by restrcited feeding. Iodinated casein alters thyroid activity which is obtained by restricted feeding (Cohn and Joseph 1960).

The addition of iodinated casein to the finisher diet not only decreased the amount of abdominal fat (representative of total body fat) , but also improved the feed conversion efficiency. Wethli and Wessels (1973) noted that lipid levels were correlated to thyroid activity and this effect has been observed here.

The exact mode of action of the beta-adrenergic agonists is unknown but it has been proposed that these chemicals act in both muscle and adipose tissue and affect fatty acid synthesis Wicks et al 1984). The effects on chickens have been less pronounced than expected (Dalrymple et al 1984) and may be due to the chicken liver being the major site of fatty acid synthesis, rather than the adipocyte. Chicken adipose tissue is unaffected by noradrenalin or porcine ACTH (Carlson et al 1964) which are catecholamines similar to the beta-agonists. Similarly, the level of oestrogen has an influence on the success of these chemicals (Stiles et al 1984) and all previous studies using lambs, steers or pigs have used female or castrated males. Hence the 'poor' effects obtained in broilers may be a result of either of the above factors.

Caffeine and theophylline act within the adipocyte and are reputed to alter the activity of the enzymes, phosphodiesterase and, in turn, lipoprotein lipase. The use of these chemicals may have advantages in reducing fat levels, The present studies show that they are unpalatable at high levels, typical of most alkaloids, but at lower levels, they may reduce fat but not feed intake or bodyweight.

The lack of change in the energy and nitrogen balance when chemicals are added to the finisher feed was unexpected. The birds were fed the treated diets for 3 days only and it is possible that critical levels of each chemical need to be reached before any effect is observed. As both cimaterol and