REDUCING BODY FAT IN BROILERS: PRELIMINARY RESULTS

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SUMMARY

In three experiments broiler chicks at seven days were restricted to different amounts of feed for 4, 6 or 10 days in an attempt to reduce carcass fat and fat pad size when slaughtered at 7-8 weeks. In the first two experiments, lines selected for high and low fat were used, and in the third, two commercial lines. In Experiment 1, reduction of intake to 35% and 50% of ad libitum for 10 days reduced carcass fat, pad size and feed conversion ratio compared to the controls but significantly reduced weight gain at 8 weeks. In Experiment 2, restriction to 24% and 30% of ad libitum intake for 10 days was again effective but 36% ad libitum for 6 days significantly reduced fat pad size. Males had smaller fat pads (% of body weight) than females, and the high fat line had more carcass fat and larger fat pads than the lean line. In this line only abdominal fat pad size was correlated with carcass fat. In Experiment 3, restriction was 19% and 23% ad lib. intake for 4 or 6 days. In one of the lines, restriction reduced carcass fat and improved feed efficiency although weight gain at 49 days was reduced following the 6-day restriction. However, in Line 1, males showed a reduction in fat pad (% body weight) and in line 2 only females showed a reduction in fat pad. Nitrogen retention and metabolizable energy was measured during 4 days following lifting of restriction in Experiments 1 and 2 There was a marginal improvement in these parameters after 10 days of restriction. It is concluded that feed restriction is a viable method of reducing carcass fat and fat pad size in broilers but implementation of these practices in the field requires further experimentation.

INTRODUCTION

Selection in broilers has usually concentrated on growth rate with little consideration being given to feed efficiency and often results in a concomitant increase in carcass fat (Pym and Solvyns 1979). Today, excess carcass fat, particularly abdominal fat, is a major industry problem. So much so that some producers in the United States are promoting "lean carcass" at a premium price. This initiative recognises also a move to reduce total fat in man's diet although a degree of fatness is desirable in broilers for both appearance and cooking.

The major problem is the abdominal fat pad which is a large, discrete fat depot and comprises up to 4% of the killed bird (Leeson and Summers 1980). Leenstra (1986) estimated that 10,000 tonnes of abdominal fat are produced in the Netherlands each year. Similar calculations would suggest that more than this amount was produced by the Australian broiler industry in 1985.

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Hood (1982) observed a significant correlation between body fat (%) and weight of fat pad. The relationships were different between the sexes but Hood concluded that the fat pad could be a useful indicator of body fatness, although changes in fat pad weight are not always associated with corresponding change in carcass fat (Dalrymple et al 1984).

Hood (1982) also characterized the development of the fat pad and found that in one strain of broilers the number of adipose cells increased until about 14 weeks; after this time adipose cell volume increased rapidly.

The subject of excessive carcass fat has been reviewed recently by Jensen (1982), Fisher (1984), Leenstra (1986) and Whitehead (1986). Post (1985) identified breed, feed, age, sex, season (temperature) and region as important factors influencing carcass fat. Of these, diet and breed are perhaps of greatest importance. Chambers et al (1981) compared strains of broilers developed in 1955 and 1978 and showed that at 47 days the latter strain had 71% more abdominal fat and 40% greater carcass fat than the former. However, at equal bodyweight these differences were negligible. Fisher (1984) concluded "that the modern broiler chicken is fatter than its forbears at a given age simply because it grows faster, but is not fatter at a given weight or stage of maturity".

It is usually accepted that, in broilers, body fat increases with increasing environmental temperature (Kubena et al 1972) at an average rate of 1.9g/kg/°C over 10-30°C (Fisher 1984). However, Farrell and Swain (1977) found in calorimetric studies that there was a reduction in fat retention with increasing ambient temperature due to declining feed intake. Protein synthesis appeared to be reduced less than fat synthesis at high temperatures.

Whitehead (1986) reviewed nutritional factors which may affect fat deposition in broilers. Manipulation of the protein to energy ratio can influence body fat, but increasing dietary protein concentration rather than decreasing energy minimizes body fat content (Pesti and Fletcher 1984). Boone et al (1980) and Arafa et al (1983) noted that as the energy to protein ratio declined, so too did the size of the abdominal fat pad of the bird. However the optimum ratio varies among genotypes (Griffiths et al 1978). The 'fine tuning' of nutrient to energy ratios may be best left to the bird. Fisher (1984) cited experiments in dietary self selection in which males had less fat than their counterparts given a single feed. Females showed the opposite effect.

Although dietary fat *per se* does not influence body fat, the inclusion of dietary fat may increase the metabolizable energy content of the diet thereby accelerating growth and increasing body fat in the physiologically more mature bird (Whitehead 1986).

A reduction in the metabolizable energy content of the finisher diet is an effective way to reduce body fat but this may incur a penalty in terms of lower weight gain (Whitehead 1986).

Feed restriction is widely practised with growing pullets to improve egg production (Balnave 1973; Johnson et al 1984). Plavnik and Hurwitz (1985) and Plavnik et al (1986) demonstrated that early feed restriction of broilers for various periods of time reduced the carcass and abdominal fat at slaughter. Feed efficiency was frequently improved.

Recently there has been interest in the use of chemical agents that can influence the deposition of fat. Large additions of salt to the diet or to the drinking water can decrease body fat (Lightsey et al 1983; Maurice and Deodato 1982) but these can have an adverse effect on performance. Thyroactive iodinated casein (Wilson et al 1983) was found to depress feed efficiency and dressed weight.

Repartitioning agents (beta agonists) can reduce carcass fat in lambs (Thornton et al 1985), rats (James and Barker 1986) and broilers (Dalrymple et al 1984). Clenbuterol has been the most widely tested agent but may be commercially less acceptable than Cimaterol which can also reduce carcass fat in broilers (R. Hood pers. comm.). However these agents do not appear to reduce fat pad size in broilers.

An interesting approach to the production of leaner meat in livestock using serum antibodies to destroy fat cells has been attempted by scientists at the Hannah Research Institute (Coghlan 1985). The concept could be extended to broilers.

In summary, there is a need for a simple strategy to reduce the excess body fat in today's broilers. Although genetic manipulation is the most likely course to follow this often has a deleterious effect on some other parameters. Given that 'fine tuning' in diet formulation has only a marginal improvement on body fat, the two most likely avenues for improvement are repartitioning agents and severe feed restriction for a short duration during early growth. This paper describes experiments using the latter approach.

MATERIALS AND METHODS

Experiment 1

Two experimental lines of chickens selected for high or low carcass fat by R.A.E. Pym, (University of Queensland) were hatched and placed in a two tier, electrically-heated brooder and fed a commercial broiler starter diet. On day 7 the birds were individually weighed and allocated to treatment groups. Each of five treatments consisted of eight chicks of mixed sex and was replicated twice. The treatments used were an ad lib. control and feed restriction (kJ/day) to 6.3 $BW^{0.67}$ for 6 or 10 days, or feed restriction to 8.4 $BW^{0.67}$ for 6 or 10 days where BW = mean bodyweight (g). Restrictions were based on the observations of Plavnik and Hurwitz (1985), where 6.3 $BW^{0.67}$ was calculated to support maintenance only. After the restriction period, the birds were fed ad lib. to 8 weeks. At 4 weeks the birds were transferred to a commercial broiler finisher diet. The birds were maintained under 24h light and initially at 33 ^{0}C which was reduced gradually over 4 weeks to 20 ^{0}C. Feed intake and body weight were measured weekly after feed restriction was lifted. Excreta were collected for 4 days immediately after the restriction period onto weighed polythene sheets. Representative subsamples were freeze-dried and finely milled. Feed subsamples were also collected over this period. Total energy of feed and excreta subsamples were measured in an adiabatic bomb calorimeter. Nitrogen content of feed and excreta subsamples was determined by micro-Kjeldahl analysis using a selenium catalyst (AOAC 1980) and distillation by the method of Ivan et al (1974).

The birds were slaughtered at 8 weeks by cervical dislocation after feed removal for 24h. Abdominal fat pads were then removed and weighed. Six pairs of male and female birds from each treatment were frozen (minus abdominal fat pads) and finely minced and subsamples taken (Farrell 1974) for carcass fat analysis. Carcass fat was determined by measuring the density of a fat/tetrachloroethylene extract as described by Usher et al (1973). The data were analysed by analysis of variance and regression analysis procedures. Means were separated using Duncan's Multiple Range Test ($P<0.05$). Two way tests were used to compare differences between sexes and lines.

Experiment 2

The experiment was conducted as above, however, the 6 treatments were as follows: ad lib. control, feed restriction to 4.2 $BW^{0.67}$ for 6 days, 5.2 $BW^{0.67}$ for 6 or 10 days, or 6.3 $BW^{0.67}$ for 10 days. Each treatment was replicated twice. Birds were killed at 8 weeks and 6 pairs of male and female birds from each treatment were treated as for Experiment 1.

Experiment 3

The experiment was conducted as in the initial experiment using two lines of one-day-old chicks obtained from commercial hatcheries. There were four treatments, each replicated three times: ad lib. control, feed restriction to 3.1 $BW^{0.67}$ for 4 days or 4.2 $BW^{0.67}$ for 6 days and feed restriction to 4.2$BW^{0.67}$ for 6 days after which the birds were immediately placed on a high energy - high protein recovery diet (RD) until week 5 when all birds were fed a commercial broiler finisher diets until slaughter. The birds were slaughtered at 50 days and nine pairs of birds from each treatment used in the determination of carcass fat using procedures already described.

RESULTS

Experiments 1 and 2, using broilers selected for high and low fat, explored a range of restrictions and times of restriction with varying results. The restrictions 6.3$BW^{0.67}$ and 8.4$BW^{0.67}$ represented 35 and 50%, respectively of ad lib. intake.

In the initial experiment, the restrictions were successful when applied for 10 days, however for 6 days there was no effect on the size of the abdominal fat pad or the amount of carcass fat (Table 1). The final weight and weight gain of the birds were influenced by the treatments. One treatment (8.4$BW^{0.67}$/6d) decreased live weight and the three most severe treatments (6.3$BW^{0.67}$/10d, 8.4$BW^{0.67}$/6d, 10d) reduced weight gain of the birds ($P<0.05$).

The birds also decreased their feed intake over the 8 week period due to the early feed restriction. Although the 6.3$BW^{0.67}$/10d treatment had a similar final weight to the control, feed intake was severely depressed. Hence, the feed conversion ration (FCR) was improved by early feed restrictlion (Table 1) and the size of the abdominal fat pad reduced. Carcass fat was unaffected by the restrictions or the duration of the restriction. The most successful treatment was the most severe (6.3$BW^{0.67}$/10d). This treatment produced decreases of 8% in body weight and weight gain, 13% in feed intake, 6% in FCR and 10% in carcass fat. However, its greatest influence was on the abdominal fat pad which was decreased by 28%.

This latter restriction ($6.3BW^{0.67}$/10d) was repeated in Experiment 2 which was designed to impose more severe restrictions and to decrease the restriction period. The restrictions, 4.2, 5.2 and $6.3BW^{0.67}$ correspond to 24,30 and 36% ad lib. intake respectively.

TABLE 1 Effect of dietary restriction on the performance of broiler chickens (Experiment 1)

Restriction	Control	$6.3.BW^{0.67}$ kJ/day 6d	10d	$8.4.BW^{0.67}$ kJ/day 6d	10d
Initial wt (g)	85^{a}	86^{a}	83^{a}	84^{a}	85^{a}
8 week wt (g)	1563^{a}	1509^{ab}	1436^{ab}	1415^{b}	1460^{ab}
Weight gain (g)	1478^{a}	1423^{ab}	1353^{b}	1331^{b}	1375^{b}
Intake (g)	3344^{a}	3212^{ab}	2902^{c}	3092^{bc}	3042^{bc}
FCR	2.27^{ab}	2.26^{ab}	2.14^{c}	2.32^{a}	2.21^{bc}
Fat pad (%)	3.37^{a}	2.92^{ab}	2.41^{c}	2.96^{ab}	2.87^{bc}
Carcass fat (%)	14.15^{a}	13.67^{ab}	12.76^{b}	13.50^{ab}	13.54^{ab}

* Values within rows with a common superscript are not significantly different ($P<0.05$)

TABLE 2. Effect of dietary restrictions on the performance of broiler chickens (Experiment 2)

	CONTROL	$4.2BW^{0.67}$ kJ/day	$5.2BW^{0.67}$ kJ/day		$6.3BW^{0.67}$ kJ/day
		6d	6d	10d	10d
Initial wt. (g)	88^{a*}	85^{a}	89^{a}	84^{a}	85^{a}
8 week wt. (g)	1525^{a}	1459^{a}	1500^{a}	1482^{a}	1457^{a}
Weight gain (g)	1437^{a}	1374^{a}	1411^{a}	1397^{a}	1372^{a}
Intake (g)	3257^{a}	3039^{bc}	3156^{ab}	3024^{bc}	2978^{c}
FCR	2.27^{a}	2.21^{ab}	2.24^{ab}	2.17^{b}	2.17^{b}
Fat pad (%)	2.70^{a}	1.90^{b}	2.58^{a}	1.90^{b}	1.90^{b}
Carcass fat (%)	14.7^{a}	13.4^{ab}	14.4^{a}	12.8^{b}	12.7^{b}

* Values within rows with a common superscript are not significantly different ($P<0.05$)

Three treatments gave similar results ($4.2BW^{0.67}$/6d, $5.2BW^{0.67}$/10d and $6.3BW^{0.67}$/10d). No decreases due to feed restriction were apparent in final weight and the weight gain of the birds (Table 2) however, feed intake was once again depressed. Unlike Experiment 1 the birds were able to compensate for loss of growth during the restriction phase and at 8 weeks had similar body weights to the controls. The reduction in feed intake reduced FCR in the 10 d restriction treatment (Table 2). The size of the abdominal fat pad was decreased by the three most severe treatments and carcass fat was reduced by the 10 d restrictions. Similar reductions in FCR and the abdominal fat pad were recorded in this experiment with the abdominal fat decreasing by 30% due to feed restriction.

The two lines used, selected for high and low fat deposition, responded similarly to feed restriction and no interactions between lines and treatment were observed in either experiment. The sex of the birds had no influence and there was no sex x treatment or sex x line interactions.

Table 3 shows the influence of sex on the abdominal fat pad and Table 4 depicts the influence of strain.

Table 3 Influence of sex on the size of the abdominal fat pad in broiler chickens (Experiments 1 and 2)

		Fat pad (g)		Fat pad (%)	
Experiment 1	Male	39.3	NS	2.5	***
	Female	41.9		3.3	
Experiment 2	Male	31.3	NS	2.0	*
	Female	31.8		2.4	

Table 4 Influence of strain on the size of the abdominal fat pad and amount of carcass fat in broiler chickens (Experiments 1 and 2)

		Fat pad (g)		Fat pad (%)		Carcass fat (%)	
Experiment 1	High fat	49.4	***	3.5	***	15.2	***
	Low fat	31.8		2.9		11.8	
Experiment 2	High fat	40.2	***	2.8	***	14.9	***
	Low fat	22.8		1.6		12.2	

In both experiments, the male and female birds produced the same amount of abdominal fat, however, on a body weight basis the female birds were consistently fatter (Table 3). As expected the high-fat line had more abdominal fat pad (both by weight and proportion) and higher levels of carcass fat (Table 4). The relationship between carcass fat and the weight of the abdominal fat pad noted by Hood (1983) was only apparent in the low fat line where a linear relationship was found in both experiments. (Experiment 1, R^2=0.39*; Experiment 2, R^2=0.44**).

The first two experiments established that feed restriction will decrease the size of the abdominal fat pad, decrease carcass fat and improve feed conversion in broiler-chickens. However, both experiments were conducted using experimental strains which did not grow rapidly. Experiment 3 was designed to examine the performance of two commercial lines of broilers, one of which is noted for its apparent "fatness" and the other being regarded as "lean". The treatments imposed were more severe than in the previous experiments but over a shorter duration.

The restrictions $3.1BW^{0.67}$ and $4.2BW^{0.67}$ corresponded to 19% and 23% respectively of the ad lib. intake of the control birds, The effects of the restrictions are shown in Table 5. The two lines differed in their response to feed restrictions. The weight gain and the 7 week bodyweight of the birds decreased as the duration of restriction increased (Table 5). As in the previous experiments, feed intake was reduced.

Table 5 Effect of dietary restriction ($BW^{0.67}$ kJ/d) on the performance of two commercial lines of broiler chickens (Experiment 3)

	Line 1				Line 2			
Restriction duration	Control	3.1 4d	4.2 6d	4.2/RD** 6d	Control	3.1 4d	4.2 6d	4.2/RD 6d
Initial wt (g)	127^{bc*}	126^{bc}	125^{c}	125^{bc}	134^{ab}	137^{a}	134^{ab}	132^{ab}
7 week wt (g)	2268^{a}	2143^{ab}	2109^{bc}	1813^{d}	2241^{ab}	2181^{ab}	2032^{c}	1851^{d}
Weight gain (g)	2141^{a}	2017^{abc}	1984^{bc}	1688^{d}	2107^{ab}	2044^{ab}	1898^{c}	1719^{d}
Intake (g)	4100^{b}	3854^{cd}	3620^{d}	3282^{e}	4447^{a}	4069^{bc}	3829^{d}	3647^{d}
FCR	1.92^{bc}	1.91^{bc}	1.83^{c}	1.94^{bc}	2.11^{a}	1.99^{b}	2.02^{ab}	2.12^{a}
Fat pad (%)	1.34^{b}	1.18^{b}	1.17^{b}	1.32^{b}	2.01^{a}	1.78^{a}	1.78^{a}	1.78^{a}
Carcass fat (%)	11.7^{c}	11.7^{c}	11.4^{c}	11.6^{c}	15.1^{a}	12.7^{bc}	13.9^{ab}	15.2^{a}

* Values within rows with a common superscript are not significantly different ($P<0.05$)

** Recovery diet

The influence of the treatments on FCR was confounded by strain differences. Line 1 was not influenced, however Line 2 showed a decreased FCR. Although Line 2 was the fatter of the two lines, the abdominal fat pad size was not influenced by restriction in either line. Carcass fat was unaffected in Line 1, however, the $3.1BW^{0.67}$ treatment reduced carcass fat in Line 2 (Table 5). No relationships between carcass fat and abdominal fat pad were evident. Although the restrictions did not influence the abdominal fat pad, a sex x treatment x line interaction was evident (Table 6). Line 1 showed a decrease in the male abdominal fat pads when restricted but no decrease in the females. The males when subjected to feed restriction showed no decrease in the abdominal fat pad whereas the females were affected by the restriction. The performance of the birds on the "recovery diet" after restriction was poorer than anticipated with 7 week weight, weight gain and feed intake being lower than the control treatment. FCR, fat pad and carcass fat were unaffected by the recovery diet.

Table 6 The influence of dietary restriction and sex on the abdominal fat pad (%) in two lines of commercial broiler chickens (Experiment 3)

		Control	3.1 $BW^{0.67}$ kJ/d 4d	4.2 $BW^{0.67}$ kJ/d 6d
Line 1	Male	1.43 [b*]	1.11 [d]	1.25 [cd]
	Female	1.24 [cd]	1.26 [cd]	1.09 [d]
Line 2	Male	1.38 [cd]	1.57 [bcd]	1.74 [bc]
	Female	2.64 [a]	1.98 [b]	1.82 [bc]

* Value with a common superscript are not significantly different ($P<0.05$)

The ability of the birds to utilize dietary energy and protein after restriction was also investigated in Experiments 1 and 2. This was measured as changes in the apparent metabolizable energy (ME) of the diet (Table 7) and in Nitrogen retention (Table 8) during the four days following lifting of restriction.

Table 7 Changes in dietary ME (MJ/kg) in broiler chickens during the 4 days following feed restriction

			Restriction ($BW^{0.67}$ kJ/d)			
Duration of restriction		Control	4.2	5.2	6.3	8.4
Expt. 1	10 days	13.18 [b]			13.43 [a]	13.29 [ab]
Expt. 2	6 days	13.01 [a]	12.80 [ab]	12.58 [b]		
	10 days	12.47 [a]		12.56 [a]	12.65 [a]	

* Values within rows with a common superscript are not significantly different ($P<0.05$)

Table 8 Changes in nitrogen retention (%) in broiler chickens during the 4 days following feed restriction

			Restriction ($BW^{0.67}$ kJ/d)			
Duration of restriction		Control	4.2	5.2	6.3	8.4
Expt. 1	10 days	50.8 [a*]			52.9 [a]	53.3 [a]
Expt. 2	6 days	53.5 [a]	48.5 [b]	46.6 [b]		
	10 days	46.2 [b]		44.4 [a]	49.7 [a]	

* Values within rows with a common superscript are not significantly different ($P<0.05$)

However, in the final experiment, the birds were increasingly unable to fully compensate as the restriction duration increased. Plavnik and Hurwitz (1985) stated that the area of compensatory growth is controversial due to both conflicting results and variable experimental conditions. The results obtained for the third experiment with commercial birds agree with those of Plavnik and Hurwitz (1985) who noted that as the restriction duration increased complete compensation became increasingly harder to achieve.

The ability of the birds, following restriction, to utilize dietary energy and nitrogen was enhanced only after the 10 day restriction treatments. These also showed the largest reduction in carcass fat (Table 2) Again, the success of this duration may be related to the capacity of the lines to synthesise protein and the abilty of the diet to furnish additional amino acids during recovery from feed restriction. Analysis has not yet been completed for the third experiment, however, it is expected that both these factors will show improvements in utilization. The object of the 'recovery diet' after the restriction phase was to ensure complete compensation and possibly additional growth if the birds could better utilize their diets. The recovery diet failed to achieve this, possibly due to feed selection by the birds as the diet was finely ground and mixed but not incorporated into crumbles.

The final experiment using two commercial strains of broilers indicates that the optimal period of feed restriction may differ between strains. Similarly, male and female birds will respond differently to feed restriction and it may be advantageous to grow male and female broilers separately, Further studies need to be undertaken to elucidate the effect of feed restriction on diet utilization. In the experiments discussed here, the birds had access to the same diet. It may be possible to increase the performance of broilers following restriction by offering diets of high nutrient concentration.

The data obtained here have shown the efficiency of early feed restriction in reducing fat deposition in broilers of slaughter weight, however, further studies need to be completed in order to make this a viable alternative to genetic selection. Some of the practical aspects of feed restriction need to be addressed. Meron et al. (1985) suggested that there are technical difficulties. They also found that birds fed restricted amounts over 6 or 10 days had less 'attractive' carcasses due to a lack 'of 'finish'.

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