ASSESSMENT OF HUNGER IN GROWING BROILER BREEDERS IN RELATION TO A COMMERCIAL RESTRICTED FEEDING PROGRAMME

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Abstract *Animal Welfare 1993, 2:* 131-152

From two weeks of age female broiler breeder chickens were fed either on a commercial daily ration (R), twice that amount (2R), or ad libitum *(AL). Motivation to eat in R and 2R birds was compared every third week with that of AL birds subjected to 3-72h food deprivation. AL and 2R birds grew three and two times faster than R birds to 20 weeks, and AL birds ate two to four times as much per day as R birds, depending on age and on whether birds of the same age or weight were compared. When feeding motivation was measured in 16min tests with an operant procedure, numbers of responses by R and 2R birds were not related in a consistent way to the time since their daily meal ended. Responses by AL birds were correlated consistently with the preceding period of food deprivation, but it was not possible to express hunger in R and 2R birds in terms of equivalent deprivation in AL birds, as intended, because feeding motivation in the two situations differed in magnitude. Instead, it was calculated that motivation to eat in R and 2R birds, from 8 to 20 weeks, was 3.6 and 1.9 times greater than that of maximally (72h) deprived AL birds. Another measure of feeding motivation with different birds, rate of eating in 10min tests, produced a similar index of hunger with 2R but not R birds. It is concluded that broiler breeders fed on the commercial ration eat only a quarter to a half as much as they would with free access to food, and that they are highly motivated to eat at all times. The modern broiler breeder industry is caught in a welfare dilemma, since on the one hand stock appear to be chronically hungry, while on the other hand less severe food restriction leads to reduced fertility and health problems.*

Keywords: *animal welfare, chickens, feeding motivation, food restriction, hunger*

Introduction

In the UK, freedom from thirst, hunger and malnutrition has, since 1983, been the first of five basic needs specified in the Introduction to all Codes of Recommendations for the Welfare of Livestock, for different species, published by the government's Agriculture Departments. These needs are often referred to as 'the five freedoms' (FAWC 1979, 1992) and are based on suggestions put forward in the Brambell Report (Brambell 1965).

Despite the recommendations, restricted feeding practices of varying severity remain a routine part of commercial production of various farm animal species. Since these practices have clear implications for welfare, it is appropriate that they are investigated to assess the extent to which they infringe the first of the five freedoms.

With poultry, the commonest form of food restriction is that applied to parent stock (breeders) of meat-type chickens (broilers). The ultimate reason is that genetic selection for faster growth in broiler progeny has been accompanied by increased appetite in the parent lines. If broiler breeders are allowed to eat as much as they want, both sexes show reduced fertility when they reach maturity and they can suffer thermal discomfort, lameness and heart failure. To avoid these problems and reduce food costs, it is normal practice to feed them on restricted rations during rearing, from the second week onwards, according to programmes recommended by the breeding companies (Hocking *et al* 1989, Katanbaf *et al* 1989). In the UK, where there are around seven million broiler breeders, these are intended to achieve body-weights at 23 weeks of 2.8kg and 2.4kg for males and females respectively. Sexes are reared separately and rations are provided daily.

Broiler breeders fed on the restricted commercial rations are much more active than *ad libitum*-fed controls and also tend to show abnormal forms of oral behaviour such as stereotyped pecking at non-food objects, over-drinking or excessive preening (Kostal *et al* 1992, Savory *et al* 1992). Such behaviour patterns are characteristic of general undernourishment, specific nutritional deficiency and frustration of feeding motivation of varying intensity in fowls (Baumeister *et al* 1964, Duncan & Wood-Gush 1972, Hughes & Wood-Gush 1973), all of which imply that hunger in restricted-fed broiler breeders may indeed be considerable. The aim of the present experiment was to assess this hunger.

Pigs are also subjected to food restriction in commercial conditions and also tend to show oral stereotyped behaviour (Rushen 1985, Appleby & Lawrence 1987). When their feeding motivation was measured by using operant conditioning, the commercial rations were shown to result in high and constant levels of hunger, even when they were made bulkier by addition of chopped straw (Lawrence *et al* 1988, 1989, Lawrence & Illius 1989). Beyond this, however, it was not possible to express the degree of hunger more precisely in terms of some yardstick of motivation. But such an index is necessary if the scale of this issue as a welfare problem is to be judged on the basis of what level of food restriction and consequent hunger is considered to be acceptable.

In the present experiment, this question was addressed in two ways. First, by comparing the recommended daily ration of restricted-fed broiler breeders with the amount eaten by *ad libitum*-fed birds at either the same age or the same body-weight. Second, by comparing feeding motivation in restricted-fed birds with that in *ad libitum*-fed ones when subjected to periods of food deprivation ranging from 3 to 72h, which was the maximum permitted by Home Office licence[1]. It was reasoned that if feeding

[1] The Home Office is the UK's government agency with statutory control over animal experiments.

motivation in the two situations was of the same order of magnitude, then it should be possible to express hunger in restricted-fed birds in terms of an equivalent number of hours' deprivation in *ad libitum*-fed controls. A further comparison was made by imposing another level of food restriction half as great as the commercial one.

Feeding motivation was measured in two ways. One was based on operant conditioning and used a progressive ratio schedule of food reward because this had previously been concluded to be more sensitive than a fixed ratio for detecting differences in hunger in pigs (Lawrence & Illius 1989). The other was based on rate of eating in the first few minutes of free access to food, which had previously been shown to be correlated with length of food deprivation in fowls (Wood-Gush & Gower 1968, Savory 1988).

Methods

Subjects and husbandry

One hundred and fifty individually marked female broiler breeder chicks (Ross 1, Ross Breeders Ltd, Midlothian, UK) were kept in a multi-unit brooder (GH Elt Ltd, Worcester, UK) for their first two weeks of life, with continually available supplies of water and a conventional 'starter' mash diet (200g/kg protein and 11.5MJ/kg metabolizable energy). At two weeks of age they were divided randomly into six groups of 25 and each group was housed in a pen measuring 2.4m x 2.4m, with solid walls 1.1m high, floor litter (wood-shavings), one water dispenser and either one or two (from five weeks with all restricted-fed birds) food dispensers. The six adjacent pens had a 14h photoperiod (0500h to 1900h, used because there were laying hens in the same house, and longer than the 8h recommended for growing broiler breeders in the Ross 1 Parent Stock Management Manual), 9-12 lux light intensity at floor level (as recommended) and 20-27°C ambient temperature (a heating element was in each pen for the first two weeks).

In four of the pens chicks were given weighed restricted rations in the food dispenser(s) once a day at 0900h, two of the pens receiving the amount per bird recommended in the above Management Manual (treatment R) and the other two receiving twice that amount (2R). The remaining two pens were given *ad libitum* supplies of food in the dispenser (AL). At three weeks the chicks' starter mash was changed to the same diet in pellet form (3mm diameter) and from six weeks until the experiment ended at 21 weeks they were fed on a 'grower' diet (150g/kg protein and 11.0MJ/kg metabolizable energy) in pellet form (5mm diameter).

Drinking water was continually available in all the pens, despite the fact that excessive drinking was evident with both R and 2R treatments, causing floor litter in those pens to become wet in a few days. This problem was overcome by changing the litter three and two times a week respectively in R and 2R pens (and once a week in AL pens). When over-drinking and wet litter occur in commercial conditions the water supply is usually removed at midday (Savory *et al* 1992). This was not done here because there would have been problems on days when feeding motivation was tested if no water had been available in the afternoon to satisfy food-related thirst of birds tested then.

Body-weight gain, food intake and mortality

All birds were weighed when they were moved to pens at two weeks and at weekly intervals thereafter until the experiment ended. Total weights of food eaten in the AL pens were also measured weekly so that daily intake per bird with R and 2R treatments could be compared with AL. The time taken by R and 2R birds to eat all their daily ration was noted regularly in the first few weeks, but subsequently only on motivation testing days. In the first week 2R birds did not eat all their ration by 0900h next morning and the residue was removed then to prevent accumulation. Mortality was recorded throughout the experiment and dead birds were sent for post-mortem examination at a veterinary laboratory.

Measurement of feeding motivation: operant conditioning

The operant system for measuring feeding motivation consisted of a food pan (capacity 150g pellets) attached to the end of a metal arm (14cm long) which rotated in a horizontal plane and was driven by an electric motor. This was all held in a frame to which was also attached a panel with a coloured illuminated perspex disc (2.5cm diameter), which was the stimulus which chicks were trained to peck at in order to receive a food reward. The disc operated a switch which moved the pan from a position which did not allow feeding to one that did.

There were five such systems, placed in front of five small wire mesh pens measuring 0.72m x 0.80m x 0.62m high; holes in the front of each pen allowed a standing bird to peck at both stimulus disc and food pan. These testing pens, which had water dispensers and floor litter, were in two rooms near the main pen area. In a third room was equipment for monitoring birds with video cameras during conditioning and testing, and a computer (Apple Macintosh SE) for controlling the operant systems. The computer also displayed and stored information on operant responses and food rewards as they occurred.

Chicks in one of the pens on each feeding treatment (ie 75 total) were conditioned to the operant systems between two and five weeks of age, several at a time in one testing pen, with a fixed ratio of one peck at the stimulus disc to 5s access to food (ie the food pan was stationary for that time). Chicks on the R treatment were fastest and those on AL slowest at learning to respond, presumably reflecting differences in feeding motivation and despite the fact that AL chicks were fasted overnight before training.

Operant testing of the conditioned birds was done every third week from 5 to 20 weeks. R and 2R birds were tested separately in groups of five, on two days. Each group was identified with leg rings of a particular colour, tested at one of five times of day (0800h, 1000h, 1200h, 1500h and 1800h), and tested at a different time at different ages according to systematic rotation. AL birds were tested similarly in groups of five, on three days, after five periods of food deprivation commencing at 0900h (3h, 6h, 9h, 24h and 48h at five weeks and 4h, 8h, 24h, 48h and 72h subsequently). The deprivation imposed on a group changed with age according to rotation. The deprivation periods were authorized by UK Home Office licence (maximum allowed 72h) and no bird was deprived more than once every three weeks.

Before each test session, the food pan of each operant system was filled with *c*120g of the pelleted diet that birds were receiving at the time. Then at the start of the session, the birds to be tested were placed separately into the testing pens and a timer was started. They were tested on a progressive ratio schedule whereby first one peck at the disc, then two, then three etc (increments of one peck) gave a reward of access to food. In the tests at five weeks the reward lasted 5s, but in all subsequent tests it was 3s. Each session lasted 16 minutes and within this period the number of responses (pecks at the disc) by each bird was recorded every four minutes. In the past, test sessions with progressive ratio schedules usually ended when the animal failed to respond for a certain period (Hodos 1961, Kennedy & Baldwin 1972, Dantzer 1976, Lawrence & Illius 1989). This was not done here because it was considered undesirable for restricted-fed birds to have the opportunity to consume large amounts of food; the length of the reward was reduced to 3s for the same reason. Numbers of pecks at food during the 3s reward were recorded for each bird in the last two sets of tests at 17 and 20 weeks.

Although the testing was done with groups of five, there were sessions when data were not obtained from all birds. On the first occasion at five weeks, six of the 25 R, nine of the 25 2R and 11 of the 25 AL birds were not properly conditioned and either did not respond or gave up after only one or two rewards; in addition, no 2R birds responded in the session at 1000h because they still had food left in their home pen then. More conditioning was done at six and seven weeks, and in the next tests at eight weeks there were two R, three 2R and three AL birds that did not respond. All of these except for one AL bird responded in subsequent tests. There were some that died (see Results), and two AL birds became unable to peck the disc because of lameness and a bent beak. All non-responders were excluded from the data analysis and when necessary, a few birds were changed from one test group to another in an attempt to ensure that there were always at least three responders in a session. Because of the reduced number of AL responders in the final tests at 20 weeks, they were reorganized into four groups and subjected to four periods of food deprivation (6h, 24h, 48h and 72h) then, instead of five.

Correlation coefficients were calculated with the AL birds' operant data at different ages, between number of hours' food deprivation and corresponding mean cumulative numbers of responses made at 4min intervals within test sessions. Mean coefficients from all ages, at 4, 8, 12 and 16 minutes, were 0.58, 0.66, 0.81 and 0.85 respectively. Since data from the whole 16min session correlated best with food deprivation in AL birds, only these (total) data were used in subsequent analysis. The main analysis was calculation of weighted (to allow for unequal sample sizes) regressions of mean total responses in the sessions, on the number of hours since exhaustion or removal of food in the home pens, in R, 2R and AL birds at different ages. If the operant data of R and 2R birds were comparable with those of deprived AL birds, it was intended to extrapolate the proposed index of hunger in restricted-fed birds (see Introduction) from the AL birds' regression equations.

Measurement of feeding motivation: rate of eating

Chicks in the other (non-operant conditioned) pen on each feeding treatment were habituated at three weeks of age to temporary individual housing in cages measuring 28cm x 18cm x 20cm in another room near the pen area. They were tested in these at four and seven weeks and subsequently in larger cages measuring 45cm x 29cm x 40cm. Each cage had a food pan (capacity 150g pellets) and water pan attached to the outside to minimize spillage.

Rate of eating tests were done every third week from 4 to 19 weeks, with the schedule at each age being the same as with the operant tests (see above, ie groups of five identified with leg rings, the same days of the week and times of day with R, 2R and AL birds, and the same deprivation periods with AL birds). Before the start of each session, the five birds to be tested were put into the individual testing cages, with water but no food available and the session started when each bird was provided with a weighed food pan containing *c*140g pellets. Each session lasted 10min and the weight of food eaten from each pan was measured every 2min to the nearest gram on a top-loading balance (Sartorius Instruments Ltd, Belmont, UK).

Unlike the 'non-responders' in the operant tests, all birds ate in the rate of eating tests, but sample sizes were reduced by mortality with R and AL birds in later tests. As before, correlation coefficients were calculated with the AL birds' data at different ages, between number of hours' food deprivation and corresponding mean cumulative weights of food eaten at 2min intervals within test sessions. Mean coefficients from all ages at 2, 4, 6, 8 and 10 minutes were 0.84, 0.85, 0.83, 0.87 and 0.89 respectively. As with the operant data, therefore, subsequent analysis, which was the same as before, was done with data from the whole (10min) session.

Results

Body-weight gain

The growth rate of R birds, fed according to the breeding company's restricted feeding programme, agreed well with the target rate in the company's Management Manual and observed mean body-weights never differed from recommended ones by more than 0.2kg (Figure 1a). Compared with R, the 2R and AL birds gained weight roughly two and three times as fast and, unlike R and 2R, growth rate of AL birds declined after about 15 weeks.

Within the three feeding treatments, mean body-weights in the two pens were always alike and at 21 weeks they were 2.18kg and 2.23kg with R, 4.13kg and 4.13kg with 2R, and 5.29kg and 5.36kg with AL. Coefficients of variation (standard deviations divided by means) in weight, within pens in different weeks, varied from 0.07 to 0.13 with R (mean 0.10), 0.07 to 0.12 with 2R (mean 0.08), and 0.05 to 0.12 with AL (mean 0.08). Thus, variation in weight was similarly low with all treatments.

Food intake

Each R bird's daily ration increased gradually from 26g at 2 weeks, when restriction started, to 94g at 20 weeks, the final week of the experiment (Figure 1b). 2R birds received twice as much as R. Over the same period the (voluntary) daily food intake of AL birds increased from 65g at 2 weeks to 200-240g from 7 to 18 weeks, and then declined to less than 200g. In the final week the intake of 2R and AL birds was about the same.

When the R birds' allowance was expressed as a proportion of the AL birds' daily intake at the same age, this fell from 44 per cent at 2 weeks to about 25 per cent from 7 to 15 weeks and increased to 51 per cent in the final week (Figure 1b). It could be argued that a comparison at the same age is not as valid as one at the same weight, since food requirements depend at least partly on body-weight. Within the weight range of R birds (0.2-2.2kg), their ration at different ages was 40-48 per cent (mean 45%) of the daily intake of AL birds of equivalent weight. Thus, AL birds ate two to four times as much per day as R birds, depending on age and on whether birds of the same age or weight are compared.

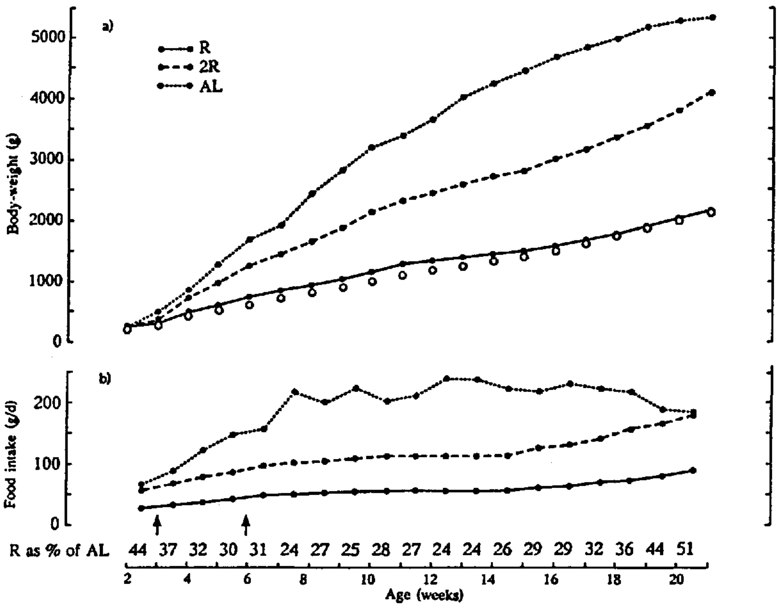

Figure 1 **Mean body-weight (a) and daily food intake (b) at different ages, of birds fed on the commercial ration (R), twice that amount (2R), or *ad libitum* (AL).**

Open circles represent the target growth rate for female broiler breeders recommended in the Management Manual. The two arrows indicate when the diet changed from starter mash to starter pellets and from starter pellets to grower pellets. The values at the bottom are daily food intakes of R birds expressed as percentages of those of AL birds at the same age.

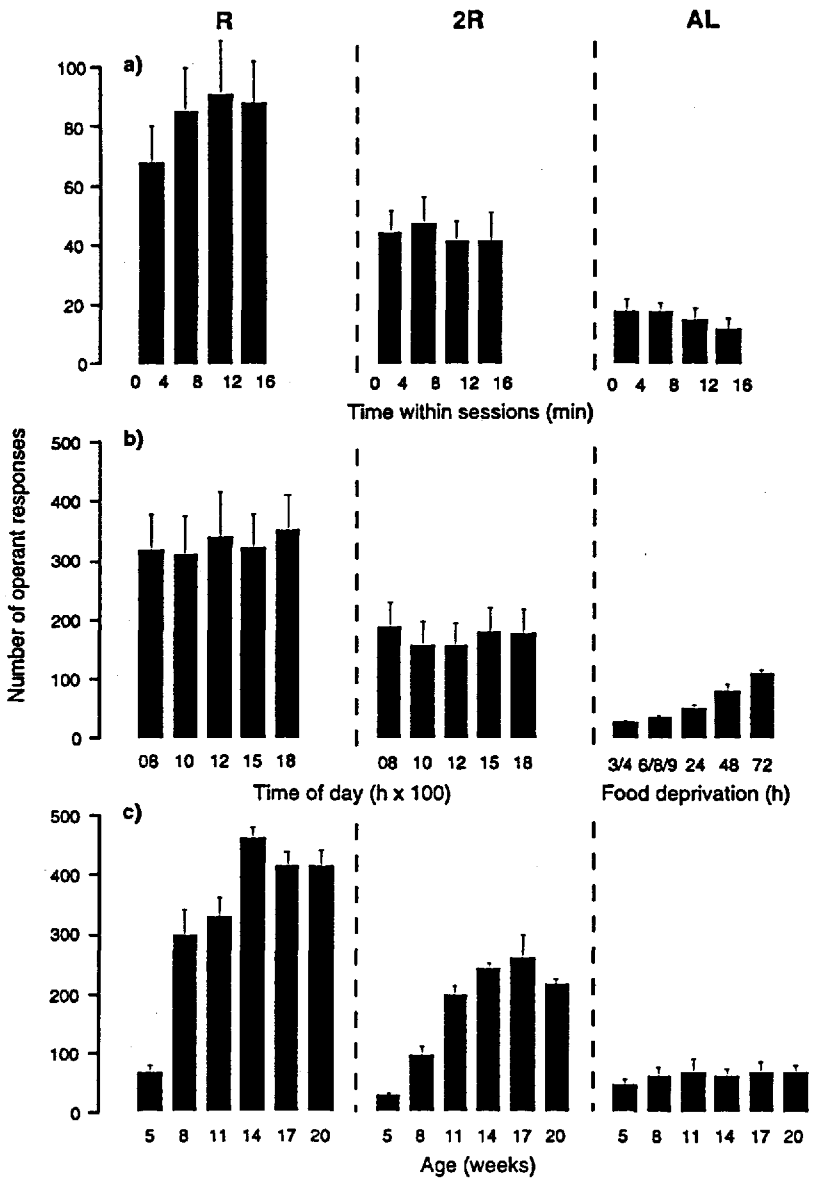

Figure 2 **Overall mean numbers of operant responses (from all tests) by birds fed on the commercial ration (R), twice that amount (2R), or *ad libitum* (AL), in each 4min within test sessions (a), totals from the whole session at different times of day or deprivation periods (b), and different ages (c).**

The food reward was 5s access at 5 weeks and 3s at all other ages. Vertical bars indicate standard errors of the means.

Time taken to eat the ration

The time taken by R birds to eat all their daily ration was 6-8h in the first week of restriction, 3-4h in the second, 20-30min in the third, 10-20min in the fourth, and less than 10min thereafter. 2R birds did not finish their ration completely in the first week (when the residue was removed to prevent accumulation); they ate all their food in 9-22h in the second week, 5-8h in the third, 30-60min in the fourth, 15-30min in the fifth, and less than 15min thereafter.

Mortality

There was no mortality at all until 11 weeks of age. Thereafter, numbers that either died or had to be culled were five (out of 50) R birds (at 12, 12, 13, 16 and 17 weeks), one 2R bird (at 12 weeks) and ten AL birds (at 11, 12, 12, 13, 14, 14, 18, 18, 19 and 20 weeks). Of these, the R birds were so lame and/or weak they could not stand (three had purulent arthritis diagnosed *post mortem*), and one was pecked about the head by other birds. The 2R bird that had to be culled was a male (the only one in all the pens) which became too aggressive. Five of the dead AL birds were so lame they could not stand (four had tenosynovitis or rupture of Achilles tendons), and the other five (which accounted for the later deaths) had liver and lung congestion leading to heart failure. Respective numbers of deaths in 'operant' and 'rate of eating' pens were two and three with R birds and seven and three with AL birds. Thus, total mortality at 21 weeks was twice as great with the AL treatment (20%) as with R (10%) and, apart from the male, there was none with 2R.

Data from the operant tests

1. Variation within test sessions

R birds tended to increase their rate of responding in the first three quarters of the 16min operant tests, presumably in an attempt to compensate for the progressive ratio schedule of food reward (Figure 2a). 2R birds, however, tended to maintain a consistent rate of responding (but not of reward) throughout the test, while AL birds tended to reduce their response (and reward) rate. Overall mean total numbers of responses in the whole session, from all tests, were 323, 167 and 57 with R, 2R and AL birds respectively.

2. Variation between times of day and deprivation periods

With R and 2R birds, mean total numbers of responses from all ages varied little with time of day, while with AL birds, they increased consistently with increasing length of food deprivation before testing (Figure 2b).

When weighted regressions were calculated, these indicated that the relationship between total responses and the time since exhaustion of the daily food allowance approached significance ($P<0.1$) at only two of the six ages when birds were tested, with both R and 2R (Table 1). Moreover with both treatments, one of the ($P<0.1$) regression coefficients was positive and the other negative. Operant responding, therefore, was not related in a consistent way to time since exhaustion of the food supply with R and 2R birds, indicating that they were as hungry after the daily meal as before it. With AL birds, however, it was related positively to time since removal of the food supply (deprivation period) at all ages, significantly ($P<0.05$) so at all except 5 weeks (Table 1).

Table 1 **Weighted regressions of mean total operant responses in 16min test sessions on hours since exhaustion or removal of normal food supply in R, 2R and AL birds at different ages.**

Age (weeks)		5[1]	8	11	14	17	20
R	*n*	5(18)	5(23)	5(24)	5(23)	5(22)	5(22)
	a	30	212	351	452	451	445
	b	1.1	9.7	-3.6	0.4	-4.9	-3.8
	t	1.7	2.9	-0.9	0.2	-3.0	-1.3
	P	0.19	0.06	0.42	0.88	0.06	0.29
2R	*n*	4(8)	5(21)	5(23)	5(22)	5(22)	5(23)
	a	9	92	189	230	198	230
	b	0.6	0.5	0.2	1.0	7.1	-2.3
	t	3.5	0.2	0.1	0.7	1.8	-4.2
	P	0.07	0.86	0.93	0.55	0.17	0.03
AL	*n*	5(12)	5(20)	5(21)	5(18)	5(18)	4(14)
	a	12	29	5	25	28	29
	b	0.6	0.9	1.9	1.0	1.1	0.9
	t	2.3	3.3	5.4	7.2	2.9	5.0
	P	0.11	0.04	0.01	0.006	0.06	0.04

[1] The food reward was 5s access at 5 weeks and 3s at all other ages

n Number of means/test sessions contributing to the regression, with total number of birds in parentheses

a Intercept ($y = a+bx$)

b Regression coefficient or slope

t b/SE(b)

P Significance of the regression coefficient (from *t*)

3. Variation between ages
Mean total numbers of responses from all times of day were lowest with all treatments at 5 weeks, when birds were not fully conditioned and when the reward was 5s access to food (Figure 2c). Subsequently, with 3s reward, they increased progressively with R and 2R birds to 14 (R) or 17 (2R) weeks, and then declined slightly, while with AL birds they remained consistent from 8 to 20 weeks. These same trends are reflected by the regression intercepts (a) of R, 2R and AL birds at different ages in Table 1.

4. Numbers of pecks at food during 3s reward
Overall mean numbers of pecks at food during the 3s reward, at 17 and 20 weeks respectively, were 13.0 ± SE 0.3 and 12.9 ± 0.3 with R birds, 11.3 ± 0.4 and 10.4 ± 0.4 with 2R birds, and 6.0 ± 0.4 and 6.2 ± 0.7 with AL birds. Only with one of these means (2R at 17 weeks) was there a significant effect (P<0.01 by ANOVA) of time of day or deprivation period. Overall means from both ages combined differed significantly between treatments (R, 13.0; 2R, 10.9; AL, 6.2; P<0.001).

At 17 and 20 weeks, mean total numbers of responses per session, from all tests, were 412, 233 and 63 with R, 2R and AL birds. These values are equivalent to 28, 21 and 10 rewards respectively. If these numbers are multiplied by the corresponding mean numbers of pecks at food per reward (see above), then mean total numbers of pecks at food per session were 364, 229 and 62 with R, 2R and AL birds respectively. If every peck was successful, which is unlikely, then these values are equivalent to 76g, 48g and 13g food eaten, since the mean weight of one food pellet was 0.210g. The weight of food available at the start of each test was *c*120g.

5. Estimation of an index of hunger in R and 2R birds
It was intended originally to extrapolate an index of hunger in restricted-fed birds (see Introduction) from AL birds' regression equations (Table 1), providing that data of R, 2R and deprived AL birds were comparable.

In the first tests at 5 weeks, operant data from the different treatments were indeed comparable, and mean total numbers of responses of R (38.7) and 2R (15.4) birds then, from all times of day, were equivalent to 43h and 5h food deprivation in AL birds respectively, as extrapolated from the AL regression then. However, this comparison cannot be regarded with confidence because the birds were not fully conditioned then, it was their first experience with the progressive ratio schedule, and the 5s reward differed from all subsequent tests.

In the tests at 8, 11, 14, 17 and 20 weeks, when the reward was 3s, the regressions of AL birds did not differ significantly (P>0.1) in either their intercepts or slopes (by analysis of covariance). A single weighted linear regression was therefore calculated from all the AL birds' data at those ages ($y = 22.2 + 1.16x$, t = 8.6 with 22 df, P<0.001). From this regression, the mean total number of responses (y) by AL birds when they were subjected to the maximum (72h) period of food deprivation (x) was 105.7. However, this value was much lower than the mean total responses by R birds in the tests at 8 to 20 weeks, which varied from 285.7 to 455.0 (Table 2). It cannot be valid to extrapolate equivalent hours' food deprivation in AL birds, as intended, with total responses of this magnitude. This is because it cannot be assumed that the AL regression would continue to be linear with hypothetical deprivation periods of more than a few days, and the R birds' responses (Table 2) would all extrapolate to periods of more than nine days.

In the circumstances, the most logical alternative index of hunger in restricted-fed birds seemed to be expression of their feeding motivation as a function of that of AL birds when subjected to the maximum permissible food deprivation (ie 105.7 responses at 72h). This was done with the total responses of R and 2R birds at different ages; means from all times of day were used because there was no consistent effect of time since feeding on their level of responding (Table 1). At all times of day from 8 to 20 weeks of age, the feeding motivation of R birds was 2.7 to 4.3 (mean 3.6) times greater than that of AL birds in the same age range when subjected to 72h food deprivation (Table 2). The motivation of 2R birds was 0.9 to 2.4 (mean 1.9) times greater, indicating that they were roughly half as hungry as R birds.

Table 2 **Mean[1] total operant responses in 16min test sessions by R and 2R birds at different ages, from all times of day, compared with that of AL birds in the same age range after being subjected to 72h food deprivation[2].**

Age (weeks)	8	11	14	17	20
R					
Mean	285.7	321.7	455.0	412.4	412.5
SE	35.4	32.4	35.3	32.6	30.9
Comparison with 72h-deprived AL	x2.7	x3.0	x4.3	x3.9	x3.9
2R					
Mean	95.8	190.7	237.9	253.8	211.3
SE	16.2	23.7	20.7	26.2	19.7
Comparison with 72h-deprived AL	x0.9	x1.8	x2.3	x2.4	x2.0

[1] See Table 1 for sample sizes
[2] 105.7, calculated from a single regression, see text
SE standard error of the mean

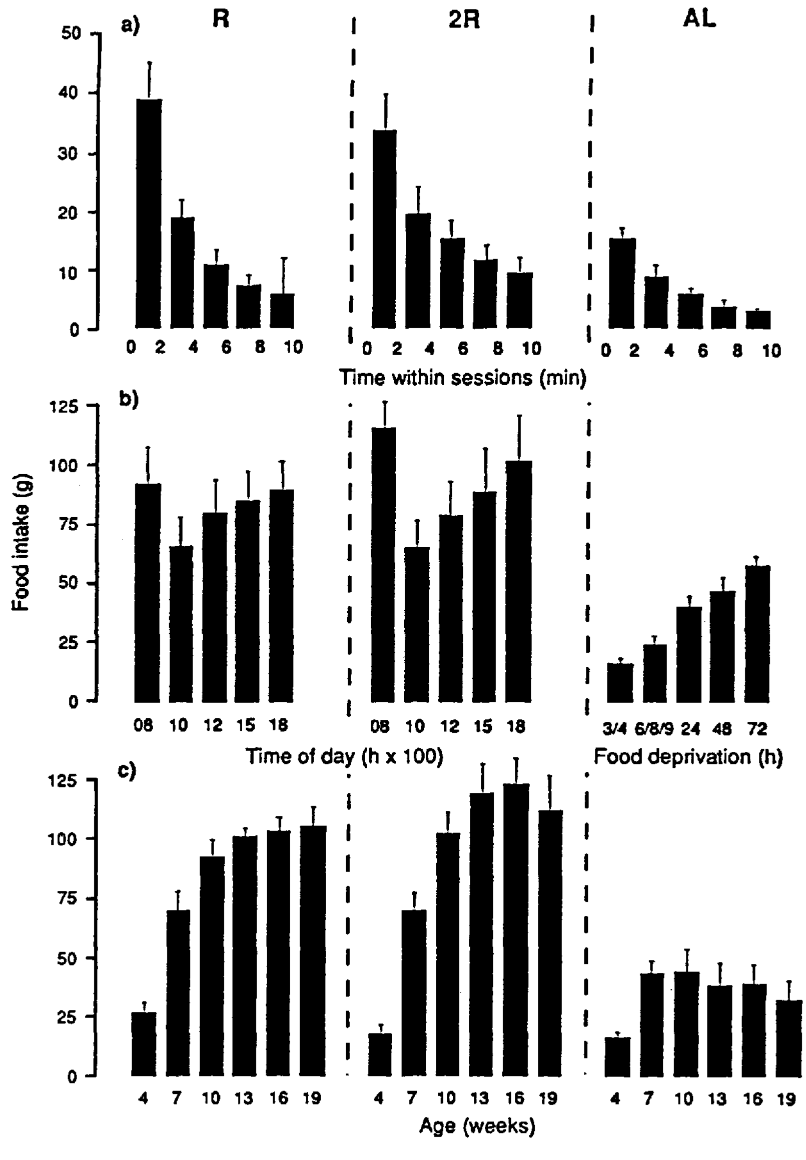

Figure 3 **Overall mean weights of food eaten (from all tests) by birds fed on the commercial ration (R), twice that amount (2R), or *ad libitum* (AL), in each 2min within test sessions (a), totals from the whole session at different times of day or deprivation periods (b), and at different ages (c).**

Vertical bars indicate standard errors of the means.

Data from the rate of eating tests

1. Variation within test sessions

Rates of eating (g/min) of R, 2R and AL birds were always highest at the start of tests and then declined progressively, as shown by overall mean weights of food eaten in each 2min of the 10min session (Figure 3a) and as reported previously with fowls (Wood-Gush & Gower 1968, Savory 1988).

Overall mean total weights of food eaten in the whole session, from all tests, were 83g, 89g and 35g with R, 2R and AL birds respectively. Thus there was no difference in eating rate between R and 2R birds during the session, but both ate faster than AL birds (Figure 3a). Similarly, cockerels ate more in a 31min test after 24h or 48h food deprivation than after 2h, but there was no difference between 24h and 48h (Wood-Gush & Gower 1968). These results suggest that there are constraints on eating rate which obscure differences between high levels of feeding motivation. This point is considered below.

2. Variation between times of day and deprivation periods

With R and 2R birds, mean total amounts eaten from all ages were lowest at 1000h in the first test after feeding time (0900h), then increased progressively in subsequent sessions and were greatest at 0800h, 23h after feeding (Figure 3b). Likewise, they increased consistently with increasing food deprivation with AL birds.

When weighted regressions were calculated of total food intake in the test on time since exhaustion or removal of the food supply, these were significant at two of the six ages with R, three with 2R and five with AL birds (Table 3). Like the operant tests, therefore, this relationship was less consistent with R and 2R birds. However, the slopes of their regressions (b) were more uniformly positive here, possibly reflecting increases in food storage capacity as their crops emptied (see below).

3. Variation between ages

Mean total amounts eaten from all times of day were lowest in the first tests at 4 weeks with all treatments, and then increased to 13 weeks with R and 2R birds, but only to 7 weeks with AL (Figure 3c). They remained much the same thereafter; these same trends are reflected by the regression intercepts of R, 2R and AL birds at different ages in Table 3.

4. Constraints on eating rate

It was suggested above that constraints on eating rate could account for the observed lack of difference between R and 2R birds within sessions (Figure 3a). Two likely constraints are an upper limit to the amount that can be consumed in each 2min, dependent on pecking rate and food particle size, and an upper limit to the total that can be consumed in a 10min session, dependent on capacity of the crop and gizzard (the two storage organs in the upper digestive tract of fowls, Savory 1985).

Table 3 **Weighted regressions of mean total food intake in 10min test sessions on hours since exhaustion or removal of normal food supply, in R, 2R and AL birds at different ages.**

Age (weeks)		4	7	10	13	16	19
	n	5(25)	5(25)	5(24)	5(24)	5(23)	5(22)
	a	17	56	91	105	91	89
R	b	1.1	1.7	0.2	-0.6	1.4	1.9
	t	2.5	2.5	0.1	-1.4	3.8	8.6
	P	0.09	0.09	0.91	0.26	0.03	0.003
	n	3(15)	5(23)	5(24)	5(25)	5(25)	5(25)
	a	13	57	84	98	102	84
2R	b	0.8	1.4	2.1	2.5	2.5	3.4
	t	1.3	2.2	3.4	2.2	3.3	4.2
	P	0.43	0.11	0.04	0.12	0.05	0.02
	n	5(25)	5(25)	5(25)	5(23)	5(23)	5(23)
	a	11	35	20	18	21	14
AL	b	0.3	0.3	0.7	0.7	0.6	0.6
	t	4.2	1.5	5.1	5.4	3.8	4.6
	P	0.02	0.23	0.01	0.01	0.03	0.02

n Number of means/test sessions contributing to the regression, with total number of birds in parentheses
a Intercept (y = a+bx)
b Regression coefficient or slope
t b/SE(b)
P Significance of the regression coefficient (from *t*)

The fact that eating rate declined within sessions just as much with R as 2R birds (Figure 3a) suggests that neither group was constrained by an upper limit to pecking rate. The second possibility, however, is more likely because in previous work with (tube-fed) fowls, a two-fold difference in size of a twice-daily meal was reflected by a significant difference in weight of the crop (and hence presumably its capacity) but not of the gizzard (Nitsan *et al* 1984). Hence the 2R birds here, which ate twice as much per day as R birds, in less than 15min, would presumably have had correspondingly greater storage capacity in their crops than R birds.

If one assumes that crop capacities of R and 2R birds were reflected by their daily rations, then the degree of crop filling in test sessions can be estimated by expressing the overall mean total amount eaten in the test, at each age, as a percentage of the ration then. The means of these were 166 ± 15 and 95 ± 14 with R and 2R birds respectively. This suggests that, in contrast to 2R birds, R birds frequently overfilled their crops in the tests (as was apparent from their behaviour), and hence that their intake was not a true measure of feeding motivation then.

Crop capacity is unlikely to have constrained food intake in the operant tests, since the estimated mean total intakes of R, 2R and AL birds then, at 17 and 20 weeks (76g, 48g and 13g, see above), were much lower than their mean total intakes in the rate of eating tests at 16 and 19 weeks (104g, 117g and 35g).

Table 4 Mean[1] total food intake (g) in 10min test sessions of R and 2R birds at different ages, from all times of day, compared with that of AL birds at the same age when subjected to 72h food deprivation[2].

Age (weeks)	4	7	10	13	16	19
R						
Mean	25.8	69.4	91.8	100.5	102.8	105.7
SE	2.2	3.6	4.9	3.8	4.9	5.0
Comparison with 72h-deprived AL	x0.9	x1.3	x1.2	x1.6	x1.7	x1.9
2R						
Mean	18.4	69.4	101.8	118.7	122.4	111.6
SE	2.5	4.1	5.2	7.0	6.6	7.9
Comparison with 72h-deprived AL	x0.6	x1.3	x1.4	x1.8	x2.0	x2.0

1 See Table 3 for sample sizes

2 29.4g, 53.6g, 73.6g, 64.7g, 61.6g and 55.6g at the six ages, respectively, calculated from a separate regression at each age, see text

SE standard error of the mean

5. Estimation of an index of hunger in R and 2R birds

The weighted regressions of AL birds in Table 3 differed significantly in their intercepts ($P<0.01$) but not their slopes ($P>0.1$). Separate regressions, therefore, were used to calculate mean total intakes of AL birds at different ages, after 72h food deprivation, for comparison with the R and 2R birds' mean intakes (Table 4), as with the operant data. In the first tests at 4 weeks, R and 2R birds ate less than 72h-deprived AL birds, and their intake then was equivalent to 58h and 28h deprivation in AL birds, respectively. In all subsequent tests, they ate more than 72h-deprived AL birds, and so, as before, no further extrapolations were justifiable. Hence the same comparisons were made here, at all ages, as those in Table 2.

At all times of day from 4 to 19 weeks, the food intake of R and 2R birds in 10min tests was 0.9 to 1.9 (mean 1.4) and 0.6 to 2.0 (mean 1.5) times greater, respectively, than that of AL birds of the same age when subjected to 72h deprivation (Table 4). For the reasons given above, it is likely that this is a true index of hunger with 2R, but not R birds. If a mean index for 2R birds is calculated from 7 to 19 weeks only, this (x1.7, Table 4) is similar to that obtained with the same treatment in the operant tests from 8 to 20 weeks (x1.9, Table 2).

Discussion

These results show that the recommended commercial restricted feeding programme, for growing female broiler breeders, suppressed growth rate and food intake between 2 and 20 weeks of age by some 65 and 70 per cent respectively, compared with those of birds that were allowed to eat as much as they wanted (Figure 1a,b). The reduction in food intake was maximal from 7 to 15 weeks, at about 75 per cent, but if birds of the same weight are compared instead of the same age, the reduction was about 55 per cent. Food intake and growth rate of AL birds here were greater than those reported in an earlier study, where diets with energy and protein contents like those here were provided in mash form (Katanbaf *et al* 1989), and it could be that such differences reflect effects of the pelleted food and/or longer photoperiod (14h) used here. Nevertheless, these results and those of Katanbaf *et al* (1989) indicate that the level of restriction applied to broiler breeders is roughly twice as great as that recommended for pregnant sows (Agricultural and Food Research Council 1990), which has been estimated to be about a 30 per cent reduction compared with *ad libitum* intake (Lawrence *et al* 1988).

It might be expected that the time taken by restricted-fed birds to consume all their daily ration (<10min and <15min with R and 2R) would reflect the need to eat as fast as possible in a group feeding situation (from two dispensers). However, when birds with the same R ration were fed individually in cages in another experiment, they took the same time to eat it all as did the grouped R birds here (J Savory, unpublished data). Presumably some birds in group feeding are more successful than others, and this is reflected by variation in body-weight gain. Even so, mean coefficients of variation in body-weight here, from all weeks, were similarly low with all feeding treatments, and near that recommended (<0.08) for commercial flocks.

The greater mortality here in AL than in R birds (20% and 10% respectively at 21 weeks) has also been found in other studies with (female) broiler breeders (Robbins *et al* 1986, Katanbaf *et al* 1989). *Ad libitum* feeding is clearly detrimental to broiler breeders' health and the present results confirm that it leads to Achilles tendon problems and (especially in older birds) deaths from heart failure. The R birds' mortality here was greater than that of restricted-fed birds in the studies referred to above. However, this could have been because wetter floor litter in their pens here due to excessive drinking (see Methods, also Savory & Maros 1993), caused the staphylococcal infection in the three birds culled with purulent arthritis. Drier litter in the 2R (and AL) birds' pens may not have favoured such presumed bacterial accumulation and, apart from the culled male, there was no mortality with the 2R treatment.

The original intention, to express hunger in restricted-fed birds in terms of an equivalent number of hours' food deprivation in *ad libitum*-fed controls, depended on measures of feeding motivation in R, 2R and deprived AL birds being of a similar order of magnitude. In most of the tests, however, R and 2R birds appeared to be much hungrier than AL birds deprived of food for 72h, the maximum period permitted under UK Home Office licence. It was therefore not valid to extrapolate values for R and 2R birds from AL birds' regressions of total operant responses, or food intake on hours' food deprivation, because it could not be assumed that the regressions would continue to be linear with deprivation periods of more than a few days. Expression of R and 2R birds' hunger as a function of that of maximally (72h) deprived AL birds seemed the most logical alternative yardstick.

Confidence in the validity of the methods used here for measuring feeding motivation, progressive ratio operant schedule and rate of eating, is reinforced by the results in two ways. First, the mean index of hunger from all operant tests at 8 to 20 weeks was twice as great in R (72h-deprived AL x3.6) as in 2R birds (x1.9), which received twice as much food. Second, the mean index from all tests at 7 to 20 weeks in 2R birds was similar with both the operant (x1.9) and rate of eating (x1.7) methods, which were totally independent.

The progressive ratio schedule was a sensitive indicator of differences in feeding motivation among feeding and deprivation treatments, as also concluded by Dantzer (1976) and Lawrence and Illius (1989), and there appeared to be no disadvantage to using a fixed (16min) test period here, rather than the more usual 'failure to respond' criterion for terminating tests. In fact, the size of this criterion has varied greatly in the past, from 30s (Kennedy & Baldwin 1972) to 15min (Hodos 1961). The rate of eating method, however, was not a sensitive indicator of high levels of feeding motivation, because it is likely that the R (but not 2R) birds' crop capacity constrained their food intake in the tests. The mean index with this method in R birds (72h-deprived AL x1.5) is therefore not a true reflection of their hunger.

It could be argued that the observed difference between R and 2R birds in the results of the operant tests might reflect a difference in their propensity to peck at the stimulus disc *per se*, rather than a difference in their motivational state. This explanation seems unlikely for two reasons. First, although 2R birds tended to peck at the disc at a steady rate throughout the test sessions, R birds tended to increase their response rate, presumably in an attempt to maintain their rate of reward (Figure 2a). Second, although R birds delivered twice as many pecks at the disc as did 2R birds in the tests (mean totals 323 and 167 respectively), pecking activities of R birds in the pens (at the empty feeder and floor litter) did not take up twice as much time (mean 22%) as those of 2R birds (17%, Savory & Maros 1993).

The conclusion that feeding motivation of R birds was 3.6 times greater than that of AL birds subjected to 72h food deprivation may seem impressive. In the past, however, periods of food withdrawal of 12 days have been used for inducing a moult in laying hens (Brake *et al* 1982), and in one extreme experiment, mean survival time during total starvation was 24 days in immature female meat-type chickens (Bierer *et al* 1965). Also, feeding motivation of AL birds in the tests was lower than expected, since they apparently made little attempt to redress food deficits resulting from even 48h and 72h deprivation. Indeed, it could be argued that AL and R broiler breeders are not really comparable, since the former are bulky and lethargic while the latter are slim and active and behave more like birds of laying strains. Here, mean proportions of time spent resting by AL and R birds in the pens, from 6 to 18 weeks, were 74 and 8 per cent respectively (Savory & Maros 1993).

Despite reservations concerning the index of hunger, the results of this experiment indicate that broiler breeders fed on the commercial ration eat only a quarter to a half as much as they would with free access to food, and that they are highly motivated to eat at all times. In addition, they show abnormal forms of oral behaviour characteristic of frustration of feeding motivation (Kostal *et al* 1992, Savory *et al* 1992, Savory & Maros 1993), and an elevated ratio of heterophil to lymphocyte white blood cells (Maxwell *et al* 1992, Savory *et al* in press), which is arguably the most reliable physiological index of stress in fowls (Gross & Siegel 1983, Gross 1990). Taken together, these four facts provide evidence that restricted-fed broiler breeders are chronically hungry, frustrated and stressed, that in their case the first of the 'five freedoms' (see Introduction) is being contravened, and hence that their welfare is compromised.

Animal welfare implications

The modern broiler breeder industry is caught in a welfare dilemma. On the one hand the level of food restriction imposed commercially may cause suffering through chronic hunger. On the other hand less severe restriction leads to reduced fertility, and *ad libitum* feeding to health problems. The dilemma is due to the genetic selection for faster growth in broiler progeny. There are various ways in which the situation might be improved. Qualitative restriction of nutrient intake, by appropriate dietary dilution with an inert or low digestibility filler, and with free access to food, might be a less stressful alternative to quantitative restriction for limiting growth rate. It may not be necessary to restrict food intake throughout the whole rearing period (Hocking *et al* 1989) and it may be possible to select new genetic lines which do not show undesirable traits with less severe restriction (Hocking & Whitehead 1990). Should such steps prove to be inadequate for improving broiler breeder welfare to an acceptable level, then a reduction in economic efficiency, involving reduced fertility or reversion of selection to slower growing progeny, may be the only alternative.

Ultimately, the question of what action should be taken depends entirely on what level of hunger is considered to be acceptable, and in reality this means acceptable to public opinion. It is not enough to say that the birds are hungry, or even that they are very hungry. What is required is an objective yardstick of hunger with which to gauge the current situation and any future changes. This experiment was an attempt to establish such a yardstick.

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