Effects of Qualitative Feed Restriction During Rearing on the Performance of Broiler Breeders During Rearing and Lay

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ABSTRACT To prevent health and fertility problems associated with excessive weight gain, broiler breeders are severely feed restricted during rearing, which may affect welfare. We compared the effects of an experimental ad libitum feeding regimen based on qualitative restriction of food intake with conventional quantitative food restriction on the performance of female broiler breeders during rearing and lay. During rearing up to 20 wk of age, control birds were fed restricted amounts of standard broiler breeder mash once daily. Experimental birds had ad libitum access to the same standard mash mixed with 400 g of oat hulls/kg of feed and increasing concentrations of Ca propionate, an appetite suppressant. Mean total mash intake during rearing was 8.12 kg and did not differ between treatments. Both control and experimental birds showed an almost linear growth curve, treatment mean body weights were always within 100 g of the target weight line, and treatments did not differ for body weight uniformity. Groups were subjected to the same quantitative feed restriction from during lay. Feeding regimen during rearing did not affect number of eggs produced, egg weight, or egg quality up to 46 wk of age. We concluded that it may not be necessary to subject chicks to severe quantitative feed restriction to achieve desirable growth curves and body weight uniformity during rearing. Qualitative restriction of feed intake can achieve desirable growth curves in ad libitum fed chicks during rearing, and such a feeding regimen does not have negative effects on hen performance during lay.

(Key words: broiler breeder, rearing, qualitative feed restriction, egg production, egg quality)

INTRODUCTION

Under commercial conditions broiler breeders are feed restricted during rearing to limit growth rate, and they may receive one small meal a day or be fed once every 2 ds (Aviagen, 2001; Mench, 2002). This quantitative restriction of food intake aims at avoiding rapid growth and high body weights, which are associated with pathological conditions, such as ascites, lameness, and mortality, and poor reproductive results, such as low egg yields, the occurrence of double yolks, and low fertility (Aviagen, 2001; Mench, 2002). However, severe quantitative food restriction frequently results in abnormal behaviors such as polydipsia (overdrinking), stereotypic pecking at nonfood objects, and increased pacing (Savory and Maros, 1993; Savory and Kostal, 1996; Hocking et al., 1997). Such behaviors are considered characteristic of frustration due to unfulfilled feeding motivation (Savory et al., 1996), and broiler breeders are widely considered to suffer from hunger during rearing (Savory et al., 1993; Lawrence et al., 2004). This raises the concern that the welfare of birds kept in such rearing systems may be compromised.

A number of attempts have been made to improve bird welfare by giving broiler breeders ad libitum access to food of which the composition has been manipulated to decrease voluntary energy and nutrient consumption during rearing (qualitative restriction; Pinchasov and Jensen, 1989; Pinchasov and Elmaliah, 1995; Savory et al., 1996; Savory and Lariviere, 2000). There is indeed evidence that such qualitatively restrictive feeding methods can abolish at least some of the apparently abnormal behaviors (such as stereotypic object pecking) that are associated with severe quantitative food restriction (Sandilands et al., 2005b). The main methods to decrease voluntary energy and nutrient intake in birds fed ad libitum include addition of a bulky dietary diluent or an appetite suppressant to feed (Pinchasov and Elmaliah, 1995; Savory et al., 1996). These methods have had limited success for several reasons. The main problem has been to accurately achieve target body weights combined with uniformity of weight gain (Savory et al., 1996; Savory and Lariviere, 2000). Birds with access to diets con-
taining a dietary diluent or an appetite suppressant generally also show an accelerating (concave) body weight curve during rearing (Savory et al., 1996), whereas the target body weight curve is almost linear between 1 and 20 wk of age (Aviagen, 2001; Savory et al., 1996).

Based on a previous experiment (Sandilands et al., 2005a), we hypothesized that it should be possible to achieve an almost linear growth curve of broiler breeders during rearing by increasing with age the dietary content of an appetite suppressant, used alone or in combination with a dietary diluent. We hypothesized, in addition, that an ad libitum feeding regimen that results in a near target body weight curve during rearing should have no negative consequences for production during lay when compared with control birds that achieve a similar growth curve as a result of quantitative feed restriction. We tested these hypotheses in an experiment with female broiler breeders up to 46 wk of age, which were past peak egg production. An analysis of data regarding the welfare consequences of the tested regimens is reported separately (Sandilands et al., 2005b).

MATERIALS AND METHODS

Experimental Design

Female broiler breeder chicks (Ross 3082) were reared for the first week of life with ad libitum access to a standard starter mash (see Table 1) in 4 groups under heat lamps. At 1 wk of age, 480 chicks were weighed, wing tagged, and distributed evenly (by weight) among treatments in a randomized block design. There were 3 treatments (T1 to T3), each with eight replicate pens housing 20 chicks. These 24 pens were divided among 4 rooms in one poultry house, with each treatment replicated twice per room. Half of the replicates were supplied with granite grit once every 2 wk. The amounts supplied per pen ranged from 98 to 194 g/week at 23 to 109 g/bird per day between wk 1 and 20 in an attempt to reach weekly pen mean body weights similar to those previously had ad libitum access to feed, the transition period was used to gradually switch birds from their experimental rearing diet to the layer diet. During the transition period, the daily mash allowance was calculated on the basis of pen-average body weight. In the first week of this period, experimental treatment groups received 75% of the mash as part of the rearing diet (i.e., including CaP and OH) and 25% in the form of layer mash. These proportions were mixed before feeding. The proportion of layer mash was then increased to 50 and 75% in the second and third weeks of the transition period, respectively. From 23 wk of age all birds only received a restricted amount of a standard layer mash (see Table 1 for diet composition). The amounts supplied per pen ranged from 98 to 194 g/bird per day and were calculated according to the average body weight and the average number of eggs produced

| TABLE 1. Composition of the basal diets used in the starter, grower and layer phases |
|---------------------------------|-----------------|-----------------|-----------------|
| Ingredient (%)                  | Starter         | Grower          | Layer           |
| Crude protein, %                | 19.8            | 15.1            | 15.5            |
| ME (kcal/kg)                    | 2,774           | 2,678           | 2,750           |
| Total lysine, %                 | 1.17            | 0.65            | 0.73            |
| Available lysine, %             | 1.09            | 0.59            | 0.66            |
| Methionine, %                   | 0.52            | 0.23            | 0.32            |
| Methionine + cystine, %         | 0.83            | 0.47            | 0.58            |
| Calcium, %                      | 1.19            | 1.23            | 2.83            |
| Phosphorus, %                   | 0.75            | 0.74            | 0.57            |
| Available phosphorus, %         | 0.50            | 0.47            | 0.35            |
| Crude protein, %                | 19.2            | 15.1            | 15.4            |

1Premix provided the following (in IU/kg of diet): vitamin A, 16,000; vitamin D₃, 3,000; vitamin E, 25; and (in mg/kg of diet): vitamin B₁₂, 3; vitamin B₆, 10; vitamin B₁₂, 3; vitamin B₂, 0.015; vitamin K₃, 5; nicotinic acid, 60; pantothentic acid, 14.7; folic acid, 1.5; biotin, 0.125; Fe, 20; Co, 1; Mn, 100; Cu, 10; Zn, 82; I, 1; Se, 0.2; Mo, 0.5.

2Aviagen Ltd., Newbridge, Midlothian, UK.
3BASF, Ludwigshafen, Germany.
TABLE 2. Dietary treatments of the control (T1) and the experimental (T2 and T3) groups
with (a) or without (b) grit supplied.1

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Feeding</th>
<th>CaP</th>
<th>OH</th>
<th>Grit</th>
<th>CaP</th>
<th>OH</th>
<th>Grit</th>
<th>CaP</th>
<th>OH</th>
<th>Grit</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1a: Control</td>
<td>Restricted</td>
<td>−−</td>
<td>+</td>
<td>−−</td>
<td>+</td>
<td>−−</td>
<td>+</td>
<td>+</td>
<td>−−</td>
<td>+</td>
</tr>
<tr>
<td>T1b: Control</td>
<td>Restricted</td>
<td>−−−−−−−−−</td>
<td>+</td>
<td>0</td>
<td>90</td>
<td>−</td>
<td>110</td>
<td>110</td>
<td>−</td>
<td>90</td>
</tr>
<tr>
<td>T2a: CaP only</td>
<td>Ad libitum</td>
<td>60</td>
<td>−</td>
<td>+</td>
<td>2.74</td>
<td>60</td>
<td>−</td>
<td>2.74</td>
<td>60</td>
<td>−</td>
</tr>
<tr>
<td>T2b: CaP only</td>
<td>Ad libitum</td>
<td>60</td>
<td>−</td>
<td>+</td>
<td>2.74</td>
<td>60</td>
<td>−</td>
<td>2.74</td>
<td>60</td>
<td>−</td>
</tr>
<tr>
<td>T3a: CaP + OH</td>
<td>Ad libitum</td>
<td>24</td>
<td>400</td>
<td>+</td>
<td>12</td>
<td>400</td>
<td>+</td>
<td>12</td>
<td>400</td>
<td>+</td>
</tr>
<tr>
<td>T3b: CaP + OH</td>
<td>Ad libitum</td>
<td>24</td>
<td>400</td>
<td>+</td>
<td>12</td>
<td>400</td>
<td>+</td>
<td>12</td>
<td>400</td>
<td>+</td>
</tr>
</tbody>
</table>

1The calcium propionate (CaP) and oat hull (OH) contents are expressed in grams per kilogram of total feed.

For all treatments, the CP contents were 200 and 150 g/kg basal mash during the starter and grower phases, respectively. Grit was supplied separately from the feed to half of the replicates once per 2 wk.

per pen. T1 birds received restricted amounts of layer mash only during the transition period.

Bird Husbandry

Each pen had initially a floor area of 4.7 m², but this was extended to 7 m² at 20 wk of age. The floor was covered in wood shavings that were replaced with fresh material as required. There was a gas heater in each room throughout the experiment and a dull emitter heater in each pen up to 5 wk of age. Mean room temperatures decreased from 27°C at 1 wk to 20°C at 5 wk of age and was maintained at 18 to 22°C throughout the remainder of the experiment. The photoperiod was gradually decreased from 23 h at 1 d, to 8 h from 10 to 146 d of age (lights on from 0830 to 1630 h). From 21 wk of age, day length was gradually increased to 15 h at 26 wk of age until the end of the study (lights on from 0800 to 2300 h). The mean light intensity at bird head height was gradually decreased from 100 lx at 1 d, to 29 lx at 7 d, and 13 lx at 16 d of age. Between 16 d and 26 wk of age light intensity was between 11 and 16 lx. Between 26 and 46 wk of age light intensity was between 32 and 36 lx.

Each pen contained 1 bell drinker and 2 feed troughs equipped with lids to avoid spillage. Two perches, each 1.5 m long and with heights of 20 and 40 cm and a set of 5 nest boxes with wood shavings were added to each pen at 5 and 20 wk of age, respectively.

Measurements

Birds were weighed weekly, and any bird that did not gain weight during 2 consecutive weeks of rearing was culled by cervical dislocation and examined postmortem. Amounts of feed added to the feed troughs were recorded daily. After each weekly weighing of birds, the weights of feed in the troughs of ad libitum fed birds on T2 and T3 were recorded. From these data, daily mean intakes per bird were calculated for each pen.

The total number of eggs produced per pen, expressed as percentage of hens housed, and the proportion classified as seconds (i.e., cracked, dirty, laid on the floor, double yolks, and otherwise problematic; e.g., calcium splashes, soft shell, misshaped) were recorded daily from 23 wk of age. Once a week, eggs produced on 1 d were weighed to calculate pen mean egg weights. Specific gravity (SG) and water conductance (WCon) of representative samples of eggs produced by all groups were measured once a week during lay. Solutions with SG ranging from 1.065 to 1.100 (calibrated by a hydrometer) were created by adding different amounts of sodium chloride to distilled water to determine egg SG. WCon was determined weekly from the water loss of eggs during incubation for 3 d at 37°C in comparison with the water loss of calibration eggs that had been incubated previously for 3 d at 37°C in a desiccator. Total eggs tested were 3,765 (SG) and 3,977 (WCon).

TABLE 3. The mean intake per bird (in kg) of feed as fed, intake of feed as fed corrected for consumption of oat hulls (FI-OH), and the intake of feed as fed corrected for consumption of oat hulls and Ca-propionate (CaP; basal mash intake), with the standard error of the mean between parentheses.1

<table>
<thead>
<tr>
<th>Feed type</th>
<th>Feed intake as fed</th>
<th>FI - OH</th>
<th>Basal mash intake</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>S</td>
<td>G1</td>
<td>G2</td>
</tr>
<tr>
<td>T2: basal + CaP</td>
<td>1.77A</td>
<td>2.74A</td>
<td>4.51B</td>
</tr>
</tbody>
</table>

a,bTreatments significantly different within feed type and period (P < 0.05).
A–CTreatments significantly different within feed type and period (P < 0.001).
1Intakes are provided for birds in treatments T1, T2, and T3 during the starter (S), grower 1 (G1) and grower 2 (G2) periods and the total of the rearing phase.
**Statistics**

All data were blocked by room and pen and analyzed with the Genstat software (Lawes Agricultural Trust, 2004). Pen means were used to analyze CV, egg weights, SG, WCon, and egg production, but individual data were used to analyze live weights. Data were examined for normal distributions, and transformed when necessary. All data were analyzed by ANOVA.

**RESULTS**

**General**

The provision of grit affected only egg SG and was, therefore, ignored in the presentation of all other results. Litter was changed, due to high moisture content, at 6, 7, 9, 11, 12, 14, 15, 17, and 18 wk of age in pens of control treatment birds and, due to accumulated droppings, at 15 wk of age in pens of experimental treatment birds during the rearing phase. Litter was not changed in pens of T2 birds up to 12 wk of age. During lay, litter was changed at 27 and 34 wk of age and topped up with fresh shavings at 21, 23, 24, and 29 wk of age in all pens.

From 10 wk of age, 4 birds in T2 were observed to have oral lesions and were culled for that reason. Four randomly selected birds from each treatment were then culled, and a postmortem evaluation was performed to investigate how widespread the problem was. Postmortem evaluations showed that all birds culled from T2 had oral lesions, especially on the tongue and lower jawbone. Several of these birds also showed some thickening of the crop, and 2 birds had gizzard lesions. For that reason all birds from this treatment were removed from the experiment at 12 wk of age. Some similar, but less severe, oral lesions were also observed up to 23 wk of age in 9 out of 160 birds on T3 but in none of the birds on T1.

During the rearing phase 9 birds out of 320 on treatments T1 and T3 were culled, and one bird (from T3) was found dead with a perforated intestine blocked with fiber. Four birds were culled for failing to gain weight (1 in T1 and 3 in T3), 4 birds (all in T3) because of oral lesions, and 1 bird (in T3) for lameness. Postmortem examinations showed that some birds had multiple symptoms (e.g., oral lesions and build-up of fiber in the gastrointestinal tract). Of the birds that had fiber in the gut, 2 were from pens that received grit, and 4 were from pens that had not. During the laying phase 2 birds on T3 were found dead (later diagnosed as a result of egg yolk peritonitis), and 6 birds were culled. One bird each was culled for being male (in T1), for broodiness combined with weight loss (in T3), and for being severely bullied (in T1). Three birds (all in T3) were culled for leg problems (one bone fracture, one bacterial infection, and one unidentified cause).

**Feed Intake**

During rearing, fresh feed intake was highest for T3 (foods containing OH) and lowest for the T1 control treatment (see Figure 1 and Table 3). The ME content of 1 g of CaP is slightly higher than that of 1 g of basal diet. A good estimate of bird ME intake is, therefore, feed intake corrected for OH consumption, assuming that the OH supplied negligible amounts of energy. Birds on T2 had higher feed intake corrected for OH consumption than T1 birds during the starter and grower 1 periods (Table 3) when they also weighed most (Figure 2). Birds on T3 had higher feed intakes corrected for OH consumption than T1 birds during the grower 2 period and the rearing phase as a whole. Intake of basal mash, however, did not differ between treatments T1 and T3 during the rearing period as a whole.

The amounts of food supplied to the T1 control birds followed guidelines closely (Figure 1). The increase in CaP of the diets supplied to T2 and T3 birds from 6 wk of age stopped (at least initially) the increasing trend in intake observed in the starter period. The increase in CaP at the start of the grower 2 period (at 12 wk of age) stabilized

![Figure 1](https://academic.oup.com/ps/article-abstract/84/8/1286/1506463/1289)

**FIGURE 1.** Mean fresh feed intake of birds up to 20 wk of age fed a quantitatively restricted diet (T1, ●) or ad libitum fed experimental diets containing increasing amounts of Ca propionate (T2, ■), or 400 g oat hulls/kg of feed and increasing amounts of Ca propionate (T3, ▲). Guidance food supply (Aviagen, 2001) is also shown (solid line).

![Figure 2](https://academic.oup.com/ps/article-abstract/84/8/1286/1506463/1289)

**FIGURE 2.** Body weights of birds up to 20 wk of age on a quantitatively restricted control diet (T1, ●) or ad libitum fed experimental diets containing an increasing amount of Ca propionate (T2, ■), or 400 g of oat hulls/kg of feed and increasing amounts of Ca propionate (T3, ▲). Target body weights (Aviagen, 2001) are also shown (solid line).
daily intake of birds on T3 for 3 wk, after which intakes started to increase again. During the actual laying period, the amounts of layer mash that were supplied to T3 birds tended ($P = 0.06$) to be lower than the amount supplied to birds on control treatment T1 (mean total intake from 24 to 46 wk of age was 24.6 vs. 25.4 kg/bird).

**Body Weights and Uniformity**

Figure 2 shows the mean body weights of the treatment groups during the rearing phase. During the starter period, birds on T2 showed accelerated growth, which resulted in body weights that exceeded target between 5 and 9 wk of age, although they did not differ significantly from T1 control birds in wk 10 to 12. Some acceleration in growth could also be observed within the starter period in treatment T3. Mean growth rate of birds on T3 was similar to that of T1 control birds during the grower 1 phase, but from about 12 wk of age the growth rate of T3 birds slightly exceeded that of T1 birds. In comparison with T1 control birds, the mean body weights of birds on T3 were lower (wk 2 to 6 and wk 9 to 12) or higher (wk 18 to 20) at $P < 0.05$ or were not significantly different (wk 7 and 8 and 13 to 17). Mean body weights of T3 birds were always within ±100 g from the target weight.

During lay the mean body weights of the T1 and T3 groups slightly exceeded target between 20 and 30 wk of age (Figure 3). Between 30 and 38 wk mean body weights increasingly exceeded target weights in both treatment groups, a gap that decreased toward the end of the experiment. There were no treatment effects on mean body weights during lay.

Table 4 shows the treatment mean body weights and their CV at different ages during rearing and lay. There were no significant differences in CV among treatments during rearing or during lay when, for both groups, the CV were lowest.

**Egg Production and Egg Quality**

Figure 4 shows that the initial increase in the egg production curve occurred slightly earlier and later than target for T1 and T3 birds, respectively. However, the observed egg production curves were very similar to the target, and there were no significant treatment effects on egg yield during the period as a whole.

Mean egg weight increased with age in parallel to the target and there was no significant effect of treatment on mean egg weight during the period as a whole (see Figure 5). There were also no significant differences between the T1 and T3 rearing treatment groups in specific gravity or water conductance at any age. The results of these measurements are shown for 3 ages during lay in Table 5. There was a small but statistically significant difference among the SG of eggs from pens that were, or were not, supplied with grit (SG were 1.0850 and 1.0856, respectively; SED = 0.00023, $P = 0.032$).

**Figure 3.** Mean body weights of birds during lay from the control group (T1, ●), and from the treatment group that had been fed ad libitum a diet containing calcium propionate (CaP) + oat hulls (OH) during rearing (T3, ▲). The target according to the breeders manual (Aviagen 2001) is also shown (solid line).

**Figure 4.** Mean number of eggs laid as percentage of number of hens housed against age by treatment during rearing: controls (T1, ●) and experimental group (T3, ▲). Weekly production curve as given by the breeders manual (Aviagen, 2001) is also shown (solid line).

**Figure 5.** Mean egg weight against bird age in the control (T1, ●) and experimental treatment (T3, ▲) compared with the target (solid line) from the breeders’ manual (Aviagen, 2001).
DISCUSSION

General

An attempt was made to apply the same management procedures, apart from feeding regimen and the provision of grit, to all birds throughout the experiment. During the rearing period, however, litter was changed only once in pens occupied by T3 birds, whereas the litter in pens occupied by T1 control birds was changed 9 times between 6 and 20 wk of age because of high moisture content. This suggests that T1 control birds consumed considerably more water or that this feeding treatment caused a large increase in water spillage compared with the T3 treatment (see Sandilands et al., 2005a). Over-drinking (Savory and Maros, 1993) or high water usage (Hocking, 1993) has been diagnosed with fiber accumulation, and 2 of those came from pens with access to grit. These numbers are too low to draw any conclusions about the efficacy of grit for the prevention of fiber accumulation in the gastrointestinal tract. In some birds fiber accumulated in the posterior intestines, in others it built up in the crop and gizzard. Grit was supplied to half of the food (Gentle, 1986). This hypothesis can easily (and should) be tested before a feeding regimen as proposed here can be advocated for use under commercial conditions.

Although overall mortality and culling were low in our experiment, they were higher for T3 than T1. There may be several reasons for this difference between treatments. Four birds on T3 were culled for leg problems. There was, however, not a single cause for these problems, and it is therefore unclear whether or not these were related to the feeding regimen. The occurrence of oral lesions was likely related to the ad libitum access of T3 chicks to a finely ground mash diet as discussed above. In several of the culled T3 birds, postmortem exams showed a build up of fiber in the gastrointestinal tract. In some birds fiber accumulated in the posterior intestines, in others it built up in the crop and gizzard. Grit was supplied to half of the replicates to measure its effect on the performance of birds fed a fibrous diet. However, only 6 T3 birds were diagnosed with fiber accumulation, and 2 of those came from pens with access to grit. These numbers are too low to draw any conclusions about the efficacy of grit for the prevention of fiber accumulation in the gastrointestinal tract for diets as used in this experiment. Grinding the OH to a finer consistency in combination with pelleting the diet could perhaps solve this issue.

Performance During Rearing

During the starter period, birds on T2 had accelerated growth, which resulted in body weights that exceeded

<table>
<thead>
<tr>
<th>Rearing treatment</th>
<th>BW 6 wk</th>
<th>CV 6 wk</th>
<th>BW 12 wk</th>
<th>CV 12 wk</th>
<th>BW 20 wk</th>
<th>CV 20 wk</th>
<th>BW 35 wk</th>
<th>CV 35 wk</th>
<th>BW 45 wk</th>
<th>CV 45 wk</th>
</tr>
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<tbody>
<tr>
<td>1 Control</td>
<td>697a</td>
<td>12.1</td>
<td>1,261</td>
<td>14.4</td>
<td>2,149a</td>
<td>13.3</td>
<td>3,696</td>
<td>8.4</td>
<td>3,984</td>
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<tr>
<td></td>
<td>(6.7)</td>
<td>(0.60)</td>
<td>(14.2)</td>
<td>(0.60)</td>
<td>(22.8)</td>
<td>(0.85)</td>
<td>(25.9)</td>
<td>(0.54)</td>
<td>(30.4)</td>
<td>(0.57)</td>
</tr>
<tr>
<td>2 CaP</td>
<td>815b</td>
<td>15.0</td>
<td>1,283</td>
<td>16.7</td>
<td>—</td>
<td>—</td>
<td>—</td>
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</tr>
<tr>
<td></td>
<td>(11.0)</td>
<td>(0.61)</td>
<td>(18.7)</td>
<td>(0.67)</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>3 CaP + OH</td>
<td>669c</td>
<td>15.1</td>
<td>1,199</td>
<td>14.3</td>
<td>2,247b</td>
<td>15.8</td>
<td>3,682</td>
<td>8.4</td>
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<td>(8.3)</td>
<td>(1.48)</td>
<td>(14.5)</td>
<td>(0.96)</td>
<td>(30.5)</td>
<td>(1.06)</td>
<td>(26.1)</td>
<td>(0.31)</td>
<td>(30.3)</td>
<td>(0.29)</td>
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<td>Target</td>
<td>660</td>
<td>1,250</td>
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<td></td>
<td>2,155</td>
<td></td>
<td>3,465</td>
<td></td>
<td>3,855</td>
<td></td>
</tr>
</tbody>
</table>

a,b,c Treatments significantly different within period ($P < 0.05$).
CaP = Calcium propionate; OH = oat hulls.
It has been achieved at an earlier age than practiced here. Treatment T3 closely followed the target growth curve during rearing, when growth rate control is most crucial to achieve desirable performance of broiler breeders. The largest difference between treatment mean and target body weight occurred in wk 20, and then the difference was 93 g (i.e., an overshooting of the target by only 4%). The correspondence between achieved and target body weights could probably be improved even further by small adjustments of the amounts of CaP or OH or both in the diet, especially in the grower 2 phase. This shows that growth rates very close to target gains can be achieved in birds that are fed ad libitum by careful formulation of dietary composition.

Birds in treatment T3 had ad libitum access to feed that combined a basal mash with a bulky dietary diluent and an appetite suppressant. It is generally thought that different qualitative diet manipulations resulting in decreased intake act via separate mechanisms. Negative effects on energy and nutrient intake caused by addition of a bulky filler such as OH, to feed are considered to be the result of a gut fill constraint that prevents animals from eating more (Kyriazakis and Emmans, 1995). How appetite suppressants, such as CaP, affect intake is not well understood, but it is generally assumed that such compounds act by affecting an animal's metabolism after being absorbed (Pinchasov and Jensen, 1989; Oyawoye and Kreuger, 1990; Pinchasov and Elmaliah, 1995). If different additions affect intake by completely separate mechanisms, combining the 2 in 1 diet is not logical. In that case, animals would be expected to simply eat until they reach the first constraint, and, thus, there would be no advantage of adding a second ingredient. In the present experiment, however, birds on T3 consumed less basal mash and gained less weight in the starter period than birds on T2. The T2 birds must have consumed more than twice the amount of CaP that T3 birds consumed (see Tables 1 and 2). It seems, therefore, unlikely that the difference in intake and performance between birds in T2 and T3 was caused by differences between the diets in CaP content alone. The intake of T3 birds could have been restricted because of a gut fill constraint related to the presence of OH. However, in a preliminary experiment in which the same ingredients were used, birds gained 40% more than target on a starter diet containing 450 g of OH/kg of feed (V. Sandilands, B. J. Tolkamp, and I. Kyriazakis, unpublished data). In a similar experiment, Savory et al. (1996) found that target weights of broiler breeders at 6 wk of age could only be achieved by diluting the diet with as much as 600 g of OH/kg of feed. It seems, therefore, unlikely that intake of T3 birds was constrained by gut fill. This finding suggests that the addition of OH and CaP interact in their effects on voluntary intake, which makes this an interesting option for qualitative manipulation of broiler breeder diets.

Good body weight uniformity is considered as important as achieving target body weights in commercial production (Savory et al., 1996; Aviagen, 2001; Defra, 2004). It has frequently been the case that ad libitum feeding of a qualitatively restrictive diet, compared with the commercial practice of quantitative restriction of feed intake, has led to lower body weight uniformity, indicated by higher CV (Savory et al., 1996). In our experiment, there was no overall effect of treatment on CV although the groups of T3 birds fed ad libitum tended to have slightly higher CV than T1 control birds in the starter and grower 2 phases. The CV of around 13% at 5 wk of age, as observed in the present experiment, are not uncommon in commercial flocks. Birds are usually graded into 3 categories when CV exceed 12%, and each category of birds is then managed separately to increase uniformity at 20 wk of age (Aviagen, 2001). Birds in our experiment were not graded and were not fed differentially, which may explain the slightly higher than desirable CV at 20 wk of age.

There were no differences in the intake of basal mash during rearing between birds in the T1 control and the T3 experimental treatments. This result suggested that the ad libitum feeding regimen we tested did not require more standard feed than a conventional quantitative feeding regimen but was associated with some additional costs related to the use of CaP and OH.

### Performance During Lay

During lay, treatment groups were managed in the same manner in order to test the hypothesis that there would be no effects of different rearing regimens that achieved similar body weight curves on egg production and egg quality. To avoid possible aggression by birds changing from ad libitum to restricted feeding, a transition period between rearing and lay was applied to birds on treatment T3. No increase in aggression was observed, and the optimum length of such a transition period may well be shorter than the 3 wk used here. Birds of both treatments were slightly overfed between 30 and 37 wk of age (as observed from body weights; see Figure 3), which might have affected the performance of our treatment groups in terms of body weight, lay percentage, and egg weight in comparison with the breeder’s guidelines.

The increase in percentage eggs between 23 and 30 wk of age, peak egg yields, and rates of decline after peak yields were all very similar for the 2 treatment groups. The ad libitum feeding during rearing of birds in the experimental treatment T3 did not result in a lower egg yield up to wk 46 when compared with control birds reared on a quantitatively restricted feeding regimen. Mean egg weights increased with age in curves that ran parallel to the breeder’s guidance curve (Figure 5), and feeding regimen during rearing had no significant effect on egg weight.

During the grower 2 period, birds in T3 received a diet containing 60 g of CaP/kg of feed consumed. Because CaP consists of approximately 30% of Ca, this addition increased the Ca content of the feed for this treatment group by almost 18 g/kg. Because the effects of such an increase in Ca content in the rearing diet on Ca absorption and eggshell quality during lay were unknown, 2 tests were performed to detect any rearing regimen effects on...
eggshell quality. WCon and SG are good measures of eggshell quality (Abdallah et al., 1993; Roland et al., 1996; Lim et al., 2003) and were, therefore, selected. However, SG and Wcon of eggs produced up to 46 wk of age and all other quality characteristics measured were not affected by the qualitative vs. quantitative feed restriction during rearing. Egg SG was the only analyzed variable that was affected by the provision of grit. The effect was only just significant and suggests that grit provision results in a very small decrease in SG and, therefore, eggshell quality. Unless this observation is confirmed in other studies, the relevance of this finding seems very limited.

Conclusions

The results of the experiment are consistent with the hypothesis that an almost linear growth curve during rearing with a desired end weight and body weight uniformity can be achieved in an ad libitum feeding regimen based on qualitative restriction of feed intake during rearing. Birds that were reared on such a regimen did not differ in any production characteristic during lay, when they were managed conventionally, from birds that were reared on a severe quantitatively restrictive feeding regimen. The results show, therefore, that it is possible to obtain good production results with broiler breeders without resorting to severe quantitative feed restriction during rearing. The tested feeding regimen was associated with some additional costs linked to feed quality manipulation and would, for that reason alone, only be recommended if such a feeding regimen would result in clear benefits for bird welfare. Should this prove to be the case, then a suitable methodology is now available.

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