S5.1
Controlled Feeding of the Breeding Bird – A Comparative Approach
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Feed restriction enhances egg production in broiler and duck but not turkey breeders. Feed restriction controls multiple ovulation in broiler breeders and ducks and leads to enhanced rate and persistency of lay. In contrast, feed restriction in turkeys does not control multiple ovulation, reduces ovulation rate and leads to poor persistency of lay. The results of a series of experiments in broiler breeders are summarised from which a theory of the effects of feed restriction on egg production in broiler breeders was developed. The theory was used to create a stochastic computer model to predict egg production in broiler breeders. *In silico* simulation experiments with the model showed that total egg production was very sensitive to changes in body weight at photostimulation and body weight gain during the first 10 weeks of lay whereas changes in body weight gain after peak rate of lay showed only minor effects on egg production. Increasing variability (CV) of initial body weight was associated with a linear decrease in mean and increased variability of egg production. Higher variability in age at first egg had little effect on the mean number but was associated with increased variability of egg production. The results were in line with experimental data and commercial experience and support the conclusion that the model will be useful for predicting the outcome of changes to the management of broiler breeders. Similar outcomes are expected in feed restriction of ducks but feed restriction is contraindicated in turkey breeders. In principle the model could be adapted for ducks and turkeys and linked to nutritional data as a comprehensive management tool for breeding birds.

Keywords: feed restriction, broiler breeder, turkey breeder, duck, hatching egg

INTRODUCTION

Feed restriction is applied to broiler and duck breeders to control body weight gain to specific targets throughout life whereas turkeys are fed *ad libitum*. The reasons for these differences will be outlined in this paper. Further details and a discussion of male breeders will be found in a review chapter (Hocking, 2009) of a recent book to which the interested reader should refer. A theory of the effects of feed restriction in female broiler breeders will be described and recent results on stochastic modelling of production responses based on this theory will be summarised.

Table 1. Body weight and yellow follicle numbers at the onset of lay in broiler, turkey and duck breeders fed *ad libitum* or restricted.

Species	Feeding	Weight, kg	Yellow Follicles	Reference
Broiler chicken	*Ad libitum*	5.3	13.5	(Hocking, 2004)
	Restricted	2.9	7.3	
Duck	*Ad libitum*	4.5	9.4	(Hocking, 1990)
	Restricted	2.7	6.6	
Turkey	*Ad libitum*	11.9	13.2	(Hocking, 1992)
	Restricted	8.3	9.9	

OVARIAN FUNCTION IN MEAT POULTRY

Selection for high growth rates in chickens, ducks and turkeys is associated with high rates of multiple ovulation and has a similar effect on rates of lay in all three species. In birds fed *ad libitum* two or more ova are released at more or less the same time and result in about half the eggs being lost for incubation through the formation of double yolked, soft shelled and misshapen eggs or, more likely, by ovulation into the body cavity where they are rapidly absorbed. Feed restriction in broiler breeders controls ovarian function by decreasing the production of follicles (Table 1) and ovulated egg yolks. Whereas there is a saving in feed costs, it is the enhanced production of hatching eggs and reduction in mortality that are the main reasons for feed restriction in breeding poultry (Table 2).

Feed restriction also controls ovarian development in duck breeders (Table 1) and leads to enhanced egg production, fertility and liveability (Olver, 1995). In semi-commercial trials optimum productivity was obtained by limiting body weight to a minimum of 65% at sexual maturity followed by an increase to 80% of *ad libitum* that was achieved simply by limiting the time of access to feed (Cherry, 1993). In spite of the very different relative growth rates of ducks and broiler chickens the responses to feed restriction are similar in contrast to those in turkey breeders which are very different.

Table 2. Body weight, mortality, egg production, hatchability and feed intakes of broiler breeder females fed *ad libitum* or feed restricted from hatch to 60 weeks of age (from Hocking et al., 2002a).

Trait	*Ad libitum*	Restricted
Body weight, kg	5.3	3.7
Mortality, %	46	4
Egg production, n	58	157
Hatch of eggs set, %	43	86
Feed intake g/d		
0-24 weeks	163	63
24-37 weeks	192	157
37-60 weeks	142	151

The ovaries of modern heavy and medium-heavy turkey breeders have too many yellow follicles (Table 1) but experimental work has generally failed to show an improvement in productivity by feed restriction (Whitehead, 1989). Many early experiments failed to control body weight to the onset of photostimulation and would not be expected to control ovarian function (see below). Subsequently, further experimental work showed that feed restriction did not reliably control the number of yellow follicles, leaving gaps between double follicles or the birds failed to commence laying (Buchanan *et al.*, 2000). Furthermore, feed restriction is associated with reduced persistency in turkeys (Crouch *et al.*, 2002; Hocking and Bernard, 1998; Renema *et al.*, 1995) in contrast to the enhancement of persistency of lay in broiler breeders (Hocking *et al.*, 2002). There may be insufficient body reserves (breast muscle) to support high rates of lay in feed restricted turkeys or they may not have had sufficient time to dissipate juvenile photorefractoriness leading to the absence of sexual maturity and poor persistency of lay in those birds that do start laying. However, in practice, body weight targets for turkey breeder hens are slightly less (5 to 10%) than their maximum potential to maintain fitness and mobility and are achieved by feeding a low protein diet rather than by quantitative feed restriction (Bentley, 2006).

In order to optimise the nutritional management of breeding birds (matching energy and protein supply to potential output at least cost) an understanding of the relationship between feed intake and the control of ovarian function is required. We have recently developed a stochastic computer simulation model based on a series of experiments with Ross 308 broiler breeders and used it to model egg production in response to changes in various management inputs.

A THEORY OF FEED RESTRICTION IN BROILER BREEDER HENS

Optimum ovarian function is defined as not more and not less than one ovulation per day and in broiler breeders is achieved by feed restriction that should follow these rules:

1. Feed restriction should be applied from 14 weeks of age to photostimulation (Hocking *et al.*, 1989).
2. A minimum body weight of 2.8 kg is necessary for the onset of lay (Hocking, 2004).
3. The growth trajectory to the target body weight at photostimulation is unimportant (Hocking, 1993).
4. The number of yellow follicles at the onset of lay is linearly related to body weight (Hocking, 2004).
5. Ovarian follicle numbers after photostimulation are linearly related to body weight (Hocking, 1996).
6. Feed allocation post peak should be reduced (Hocking, 2004; Hocking *et al.*, 2002).

Based on these experimental observations a stochastic model was developed to simulate the egg production of broiler breeders in response to changes in body weight (Alvarez and Hocking, 2007).The production of eggs from an individual bird was based on a model with 5 equations relating follicle numbers to body weight and rates of lay associated with different rates of ovulation. There were 5 input parameters: body weight at photostimulation, daily weight gain to peak and post peak; mortality (proportion per week) and the rate of increase in the proportion of birds not in lay by week. The model was run for 500 iterations for each set of input variables. The model accurately predicted the egg production from a commercial trial (185.0±0.76 eggs predicted compared with 187.9±1.64 observed) and in 3 out of 4 small scale experimental treatments (Alvarez and Hocking, 2007).

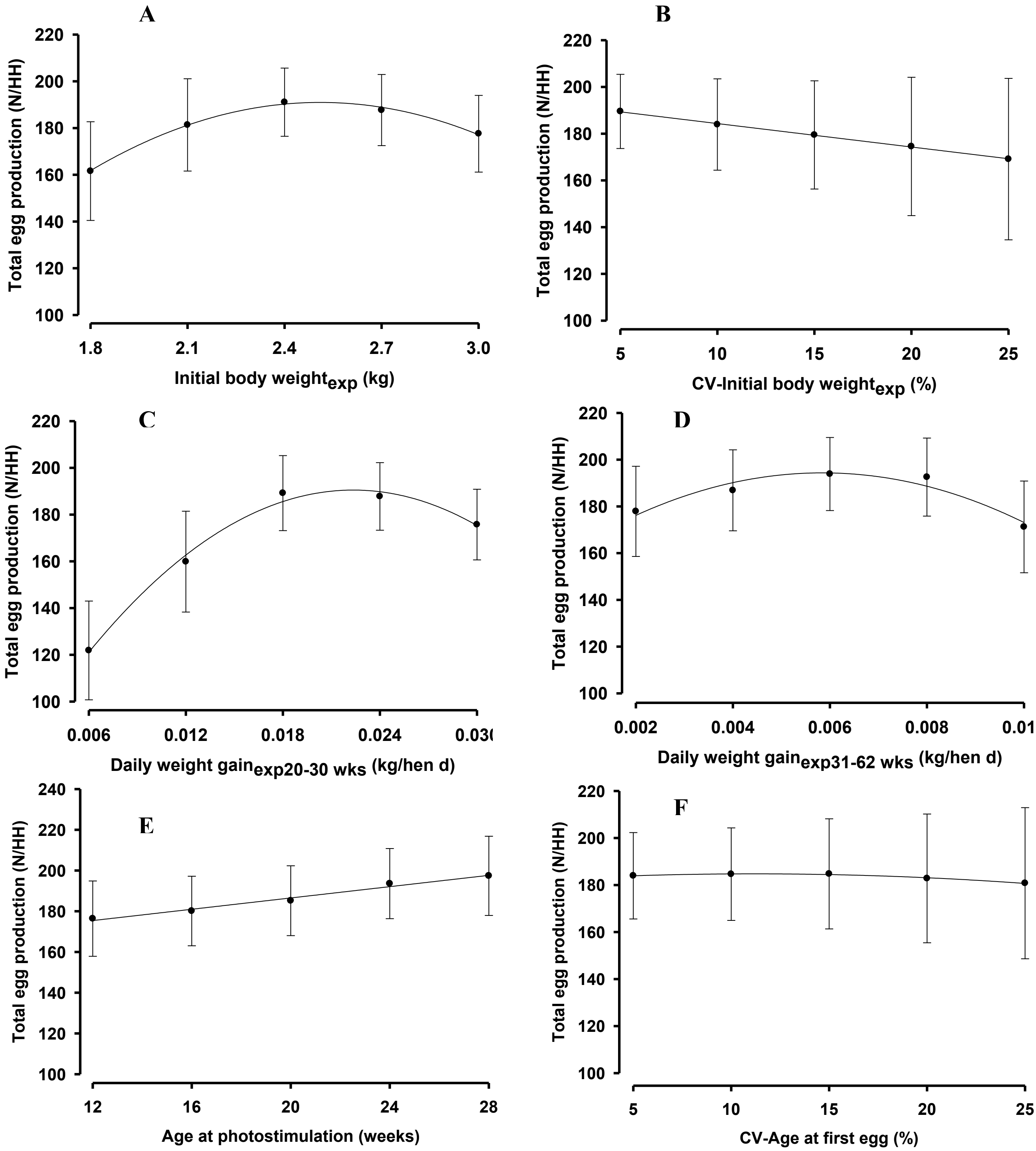

Figure 1. Effects on total egg production from 20 to 60 weeks of age of varying body weight at the onset of lay (a), the CV of body weight (b), daily weight gain from 20 to 30 weeks (c) or 30 to 60 weeks (d), age at photostimulation (e) and the CV of age at first egg (f) (from Álvarez and Hocking, 2009a).

The model provides a logical basis for future prediction and *in silico* experimentation in broiler breeders. Thus Álvarez and Hocking (2009a) investigated the effects on egg production of differences in initial body weight, daily weight gain during lay, age at sexual maturity, variability of body weight and variation in the age at first egg that would be extremely time consuming and expensive to conduct in experimental conditions. The results of this simulation exercise are summarised in Figure 1. The results suggested that total egg production was very sensitive to changes in body weight at photostimulation and body weight gain during the first 10 weeks of lay whereas changes in body weight gain after peak rate of lay showed only minor effects on egg production. Increasing variability of initial body weight was associated with a linear decrease in the mean and increased variability of egg production. Higher variability in age at first egg had little effect on the mean number but was associated with increased variability of egg production. These results are in line with experimental data and commercial experience and suggest that the model has a sound basis for commercial application. Furthermore, many papers in the scientific literature (e.g. Robinson *et al.*, 2007) report deleterious consequences of relatively small changes in target body weights during rearing on subsequent egg production and are consistent with the theory. In a second paper (Álvarez and Hocking, 2009b) showed that the model could be successfully modified to simulate egg production in a tropical environment where persistency of lay and total egg production were high.

Álvarez and Hocking (2009a) identified research areas where experimental information was lacking and noted several limitations of the model that require further experimental validation. Specifically, the model is based on relatively old data on the body weight, yellow follicle numbers and egg production of broiler breeders fed *ad libitum*. The ovulation sequence was based on the pattern of egg production in a single experiment as was the rate lay of single yolked eggs from a multiple ovulation. Both variables are difficult to measure and require further experimentation to validate or modify their assumed values. Lastly, the lack of effect of different rates of gain leading up to the onset of lay on subsequent ovarian function and rate and persistency of lay should be confirmed.

A simulation model of nutritional responses based on an empirical description of body weight and reproduction in broiler breeders and experimental data on efficiencies of nutrient utilization has been outlined by M.K. Nonis (in Fisher and Gous, 2009). The biological model described above could usefully be combined with this model of nutritional responses to optimise the management of broiler breeders both generally and in specific flocks in a dynamic approach to flock management. In principle the principles of the model could be adapted for duck and turkey breeders.

ACKNOWLEDGMENT
The research on which this paper is based was funded by Defra and the Roslin Institute is supported by a core grant from the BBSRC.

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